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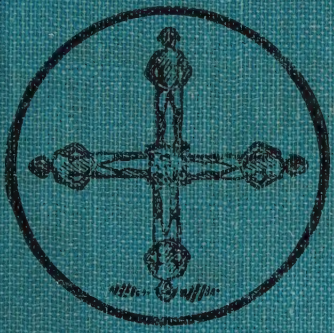

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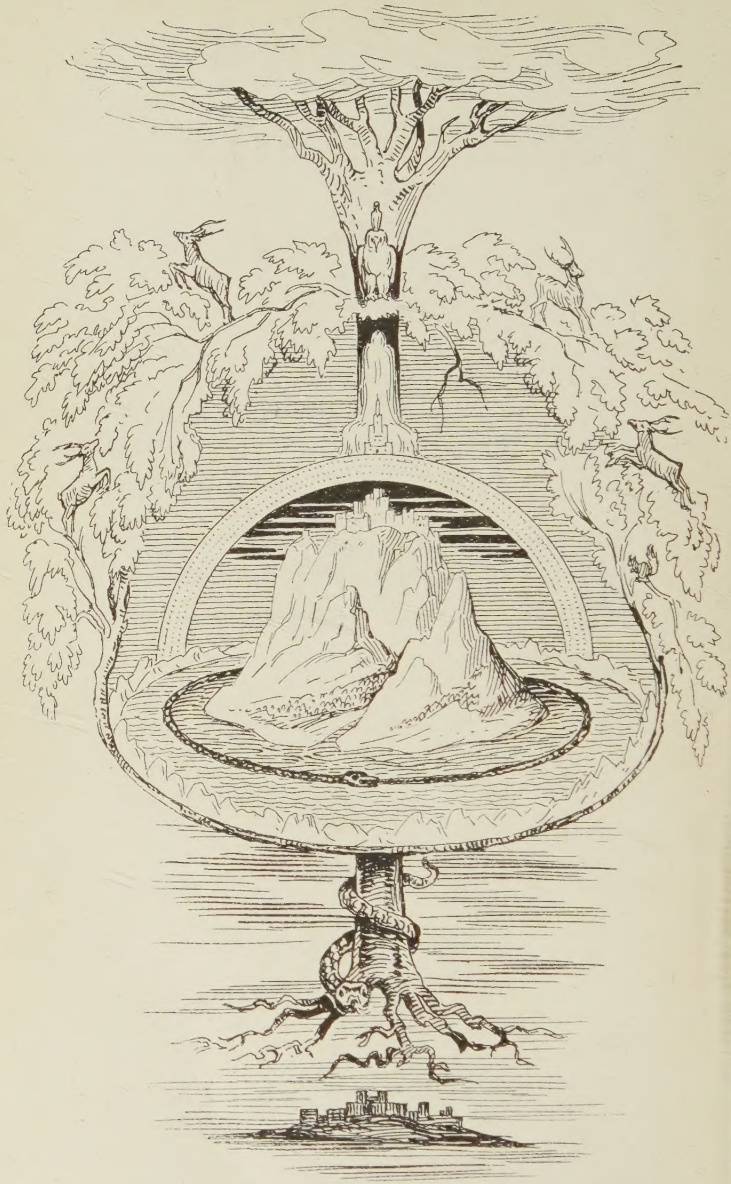
'Geography is an earthly subject but a heavenly science.'

EDMUND BURKE.

'We stand on a microscopic island of knowledge amidst the inconceivably vast ocean of the unknown.'

CAMILLE FLAMMARION.



The Earth according to Scandinavian Mythology. See page 14.

# THE PRINCIPLES

OF

# GEOGRAPHY

## PHYSICAL & HUMAN

BY

E. G. SKEAT, Sc.D., F.G.S.
(MRS. WOODS)

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Circular diagram on the cover is based on Cosmas, about A.D. 540, to prove that the Earth is not a globe. (See p. 22.)

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# PREFACE

THE original inspiration for this work was the position of bewilderment and difficulty in which the student of geography finds himself when suddenly translated from the world of beckoning books and ever-willing teachers to the intense isolation—in these respects—of the school. Even if the latter is situated in a large town, where a good supply of books is available, the busy teacher has little time for research, and needs to have his tools always at hand. We have travelled far since the mid-Victorian days when a knowledge of lists of capes and bays or exports and imports was considered 'education', and the unfortunate teacher, instead of being able to cling to a solid never-changing rock of crude fact, is launched in his own tiny boat upon broad seas of experiment and conjecture, where the most careful steering is necessary if he is not to be swamped by the waves of conflicting hypotheses or swept away by the current of side issues. To make matters worse, although most school subjects have, to some extent, their limitations, not so geography. A geologist the geographer should be, or he has no solid basis on which to build; a meteorologist and something of a physicist; a chemist, in order to deal with the composition of air, the nature of rocks, soils, &c.; a biologist and an oceanographer, an anthropologist, an ethnologist, an archaeologist, an historian and a traveller. To these powers he should add the mind of the logician for the harmonizing of facts and theories, and if, then, he also possesses the 'inward eye' of the poet and some artistic sense, he will be able to clothe the dry bones of fact with the rainbow raiment of romance. Thus the world will appear, not a mere dull muddle.

of streets and houses separated by stretches of silence, bu a living whole, replete with beauty and meaning, for

> Earth 's crammed with heaven
> And every common bush afire with God,
> But only he who sees takes off his shoes.

This is the spirit we want to instil into the younger citizens wh have to face a different world from the comparatively cal prosperous days of the Victorians, and they must face it wit more courage and more initiative if they are to win their wa through. Geography is the science of initiative, for by means o it we establish our relations with the world, and without it we ma easily lag behind in the march of progress. Geography is a kin of mental wireless through which we enter into the thought and feelings of other races and realize their activities and poten tialities ; combined with the gift of tongues, it forms the essenti equipment of the pioneer and furnishes the key to many of th Earth's secrets. If a certain lordly indifference to the feeling of others has in past time caused us to stamp on the minds o other civilized races a character not our own, that can be so n longer. Just as a certain and intimate knowledge of geograph on the part of leaders guided us safely through the grea world crisis, so now, with enlightened eyes and broadened views must we try to take our share in the heavy burden laid upo humanity.

The desire to produce this book was implanted in me by m friend, Miss Beatrice Clay, of the Queen's High School, Chester whose prophetic vision, in the early days of 1911, led her to se that the science of geography had a great future. Its existenc is, however, due to the kindness of the late Professor Herbertson who saw its early stages and gave every encouragement for it continuance ; the late Mr. G. W. Palmer of Christ's Hospita

also contributed greatly to its value by his most exact and careful criticisms, which dealt with the whole work, except the section entitled ' The Biosphere '. For many valuable notes and suggestions as to this latter section I am indebted to Professor J. L. Myres, and to Mr. J. A. McMichael, H.M.I., for his remarks on ' Tides ', and to Mr. O. J. R. Howarth for kindly reading the proofs.

I desire to thank most warmly Miss K. Chandler Thomson for her willing collaboration, which enabled her to express in each drawing the geographic idea, subordinating the artistic claim to it. As regards the original photographs, sketches, &c., I laid my sisters, friends, and pupils largely under contribution and have tried to acknowledge the debt in each case. My principle throughout has been to obtain a concrete example, indicating its exact locality, as unlocated examples seem to me valueless.

Finally, I wish to express my thanks to the publishers, who were willing to wait all through the war, while I did other work, and for some time afterwards, while the necessary revision was in progress.

I hope that the many teachers and students of geography in the various schools I have visited, as also the far greater number that I have not seen, but who are laboriously pursuing the same paths, will accept this book as a small token of fellow-feeling and regard.

E. G. W.

CAMBRIDGE,
*June* 27, 1922.

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*Frontispiece.* The Earth according to Scandinavian mythology. The Earth, disc-shaped, is upheld by the great ash-tree Yggdrasil, which has three roots, one towards Heaven, another towards Hell, and a third near the abode of the giants. In the branches of the Earth-tree are caught four harts, the four winds, and the little squirrel Ratatösk travels up and down bearing messages between the snake, Nidhögg, gnawing at the lower root of the tree and the eagle, with a hawk between his eyes, who keeps watch above. Below the eagle is the sacred Urda Fount, and beside this the palace of the three Fates, who dwell above the arch of the rainbow that spans the world. In the midst of the Earth, which forms the centre of the disc, is the city of the gods, probably on a hill with man's abode clinging to its foot. The land is encircled by the ocean, bearing the ice-bound dwelling of the giants on its outer rim, and, in the ocean, floats the great Midgard serpent.

The drawing is only an attempt to visualize the Scandinavian cosmogony, which forms part of a complicated mythological system with allegorical interpretation.

# SECTION I. INTRODUCTORY

## GENERAL EVOLUTION OF IDEAS REGARDING THE EARTH AND ITS RELATION TO THE SOLAR SYSTEM

### I. The Shape of the Earth

*Ancient Beliefs.* From the very earliest times the shape of the Earth has been a subject of discussion and speculation. The first general theory was that the Earth was flat, just as to a child the Earth is flat because his powers of perception are limited. At the same time, the early philosophers were quick to note that the limit of vision was always a circle, at the circumference of which the Heavens and Earth apparently met.[1] The belief held by the Babylonians, Hebrews and other races alike, is poetically described in the Homeric legend, where the Earth is represented on the shield of mighty Achilles as a circular plane surface, bounded by a great river, Okeanos. The same features appear on the earliest known map, constructed by the Babylonians about the eighth century B.C. (fig. 1).

The impossibility, to some people, of imagining so great a disc hanging unsupported in space was got over by the provision of all sorts of fantastic supports. In the Hindu legend, one or as many as four elephants standing on the back of a huge swimming tortoise served the purpose (fig. 2), whereas the Northmen, much later, described as upholding the Earth a mighty ash-tree which, rooted in Hell, sent up its branches to Heaven (see frontispiece and p. 14).

To the Greeks, perhaps the earliest geographers, the Earth was a disc, but they concerned themselves mainly with the habitable part, or 'oikoumene', which, from east to west, seemed

[1] To this day the Polynesian word for a stranger means 'heaven-burster', meaning that he must make a hole in coming through from another world.

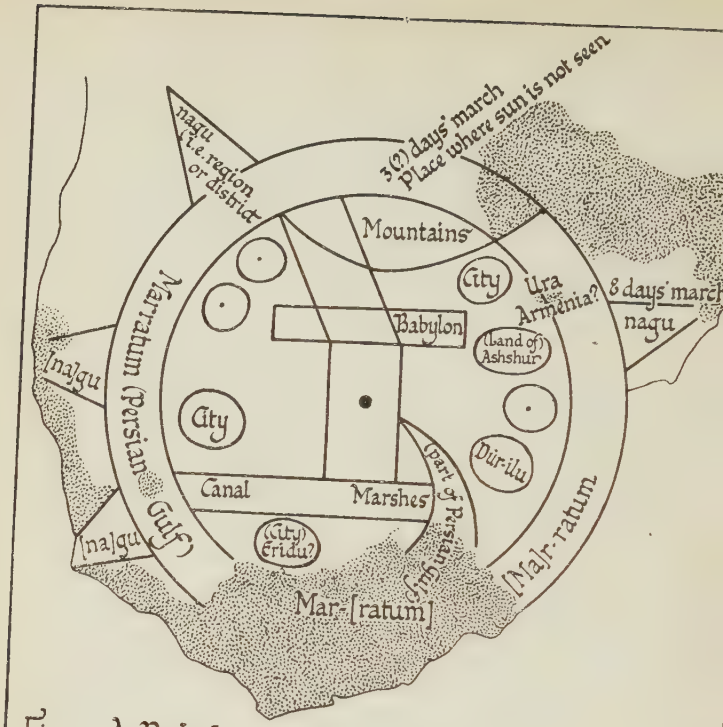



Fig. 1. A Babylonian World Map

FIG. 1. A Babylonian World-map. [B.M. 92, 687.] This is a tablet dark brown clay belonging to the late Babylonian period. The dot the middle was no doubt used as a centre by the draughtsman when drawin the two outer circles. The part enclosed by the inner circle shows Bab lonia, Assyria and the neighbouring regions as a circular plain surroun by the waters of the Persian Gulf, which is here the counterpart of world-encircling 'river of Ocean' imagined by the Greek geograph the curving inlet being an arm of the gulf. The Euphrates flows acro the central plain in a direction evidently intended roughly for north south, dividing the rectangular city of Babylon, situated on its up portion, into two unequal parts. The smaller circles represent ot Mesopotamian cities. The positions assigned to Assyria and Armenia show the great inaccuracy of the orientation. At the top of the map a the words '3(?) days' march, place where Sun is not seen'. The triangle projecting beyond the outer circle stand for regions beyond the gul which are quite vaguely defined. In the north are shown mountain the source of the river, and at its mouth in Chaldaea, a canal and marshes The drawing shows outlines only for the sake of clearness.

The shading shows where the surface is partly broken away.

almost boundless in extent, while northward and southward a navigable limit was speedily reached. The tendency to count the most extensive direction as length and to put the more important parts at the top or in the centre are features shown in the earliest maps, where the east (including the Earthly Paradise, India, &c.) is at the top, Jerusalem, in the near east, forms the centre, and the British Isles are at the outermost

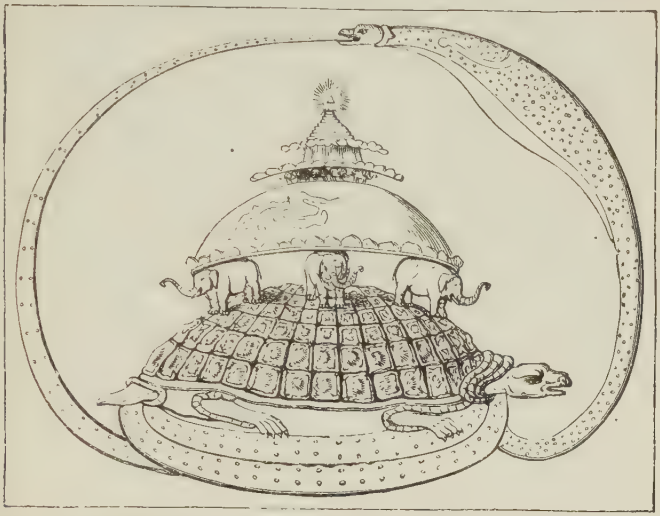


Fig. 2. The Earth as represented by a Brahmin. The abode of men is situated between that of the gods, above, and the infernal regions, below. The whole is supported by four elephants on the back of a tortoise, the symbol of force and creative power. This rests on the great serpent, the emblem of eternity.

limit of the habitable world. The Hereford map, drawn as late as 1307, shows how all these ancient beliefs even then still held the field, as practically no addition was made to geographical knowledge in this connexion from the time of Ptolemy till the fifteenth century (figs. 3*a* and 3*b*). The idea of length in connexion with the east and west direction still survives, curiously enough, in the term ' longitude ', this meaning distance east and west ; latitude or breadth being distance north and south. These terms—or rather the Greek equivalents—which would doubtless now have been

FIG. 3*a*. Map drawn by Richard of Aldingham about 1307, and preserved in Hereford Cathedral.

FIG. 3*b*. Key to the same

bestowed conversely, originated with Ptolemy, who, building up his system largely on the notions conceived before his time, naturally reflected their influence.

Until about the sixth century before Christ, it was definitely believed that the Earth was disc-like in shape, fixed and supported in space. The primitive idea of the all-encircling ocean is preserved up to the present time in the hymn :

' And round it hath cast like a girdle the sea.' [1]

*The Earth a ball.* One of the Seven Sages, Thales, is usually credited with the doctrine of the spherical shape of the Earth, but this idea more probably originated with his pupil Anaximander (610–547 B.C.), who taught that it was a solid body hanging freely in the centre of the hollow sphere of the starry Heavens. The theory of the Earth as a fixed ball, with other bodies revolving round it, was the accepted view of Pythagoras and his disciples, who held that the sphere, being the most perfect solid figure, was the only one worthy to circumscribe the dwelling-place of man.

Two centuries after Pythagoras, Aristotle (384–322 B.C.) used in proof of the Earth's roundness the selfsame arguments that we find repeated in the geography books of to-day. He noted :

1. The tendency of matter to fall together towards a common centre.

2. The circular shadow cast by the Earth on the Moon during an eclipse.

3. The apparent shifting of the positions of the stars as we travel from north to south, also the disappearance of some and the appearance of others.

*The Earth a moving ball.* The next great step was really taken by Aristarchus of Alexandria (280–264 B.C.), who should have had the glory that 1,800 years later fell to the lot of Copernicus, when he announced as a new discovery that it was the rotation of the Earth and not the Sun's movement that gave the appearance of sunrise and sunset. Unfortunately, Aristarchus was

[1] First published in Bickersteth's *Psalmody*, 1833. The word ' girdle ' is unfortunately altered to ' mantle ' in the *Ancient and Modern* version.

ages ahead of his time and obtained no following, for his theory gave far greater magnitude to the Universe than could be credited even by so learned a man as Euclid.

*First attempt to measure the Earth.* Eratosthenes (276–196 B.C.), whose methods are given below, was the first to attempt actual measurement. In addition to his other work, he undertook to determine the length and breadth of the habitable world or 'oikoumene', and estimated that it occupied less than one-fourth of the surface of the sphere. For announcing that his chief task was to 'reform the map of the world', Eratosthenes drew upon himself the censure of Pliny, the great naturalist, who referred to such an exploit as 'impious', so great even in those early days was the dread of innovations!

*Ptolemy's System.* Ptolemy,[1] writing about A.D. 150, made for himself a great name as a geographer, and the System of the Universe, as propounded by him, gained acceptance for about 1,500 years. Ptolemy was not so much an original worker as a systematizer, in that he reduced to order all the hitherto disconnected facts that had been previously discovered and built them into a system. This was based on the doctrine of the spherical form of the Earth, but its author, unfortunately, insisted that the Earth was fixed in space and rejected all arguments to the contrary. The Ptolemaic system formed the basis of the beautiful descriptions of Dante and of his great poet-successor, Milton; the latter, only at the end of his life, began to hesitate between this and the Copernican theory then beginning to gain ground. According to this idea the Earth, a fixed sphere, is enclosed in a series of hollow revolving spheres, each clear as crystal and having, fixed upon it, a planet or the constellations. The gentle clashing sound made by these crystal globes was supposed to be heard occasionally in the silence of the night and gave rise to the expression 'music of the spheres'. Ptolemy's choice of the Fortunate Isles (the Canaries), as his point of departure for

[1] Ptolemy, in his mathematical work, Ὁ μέγας ἀστρονόμος, divided the circle into 360 parts, which he called τμήματα.

In the network of parallels and meridians on the surface of his map of the world, the lines were curved for the first time.

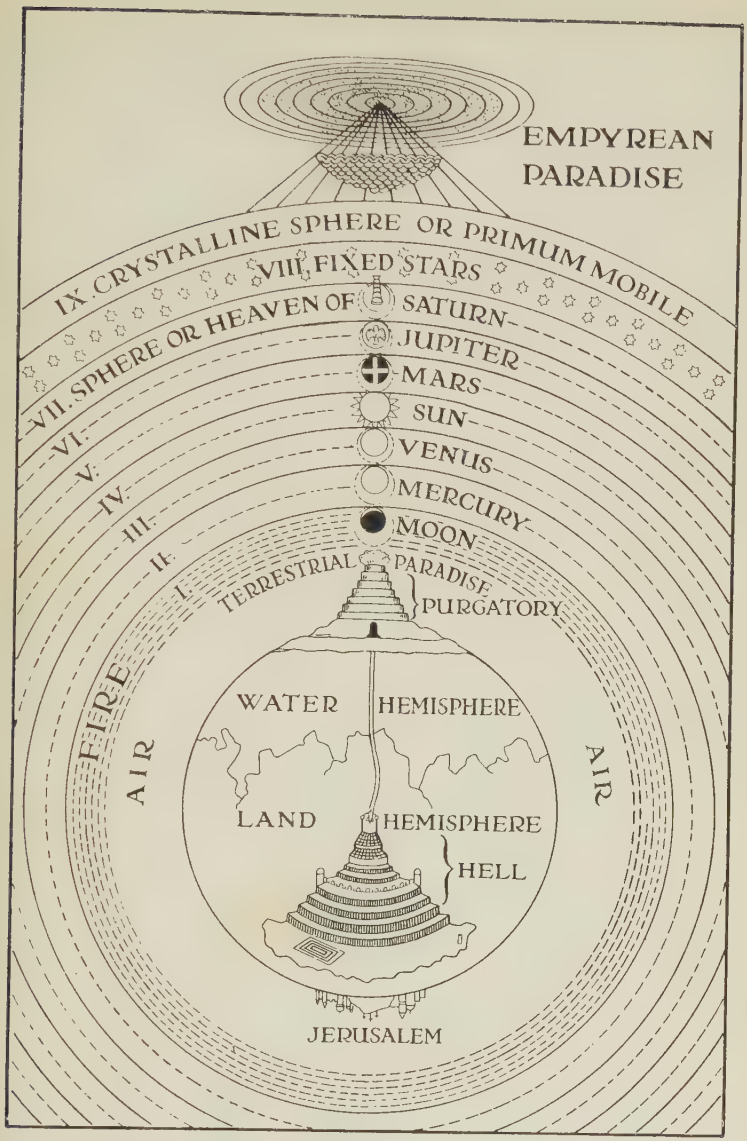



FIG. 4. The Ptolemaic system of the Universe as described by Dante.

measuring longitude, survived in the fact that they were retained as zero-point for the meridians up to the middle of the last century, and are still found on some Austrian maps of to-day. Even his mistakes, in a way, won him distinction, for the error made in computing the distance to India westward, a miscalculation of about 4,000 miles, gave immense encouragement in later days to Columbus and other explorers who, trusting these measurements, thought the Earth much smaller than it really is.

*The 'Dark Ages'. Revival of ancient Myths.* Then, gradually, followed the period of time frequently called the 'Dark Ages' when, after the dismemberment of the Roman Empire during the fourth century, knowledge seemed to remain stationary and exact reasoning based on patient investigation was at a discount. Geography now, by degrees, passed into the hands of the theologians, and any view involving the least departure from the literal wording of the Scriptures was regarded as heresy and punished with the utmost severity. So great, indeed, became the power of the Church that, even as late as 1633, Galileo was forced by the Inquisition publicly to renounce the Copernican theory. Apart from this, any one might propound a theory, no matter how childish and arbitrary, provided his personal influence was sufficiently strong to obtain him a following. For instance, about A D. 540 Cosmas, a Christian merchant, writing to confound the 'wicked folly of the Pagans', demonstrated by a drawing that the Earth was not a globe, seeing that if it were so, four men standing on different sides of it could not all be in an upright position (see cover). He also invented the theory, frequently quoted, of the existence of a huge mountain in the north which serves to obscure the Sun at night. The expression 'the four corners of the Earth' proved its form, he said, to be a rectangular plane, and the Heavens, needing support, were probably upheld by four pillars at its corners.[1]

In spite of the fact that geographical knowledge almost died out in Christendom, it was kept alive by the Arabs, who used a translation of Ptolemy's work which they called Almagest.

[1] Cf. the 'four corners of the earth' (Rev. vii. 1).

Their voyages, combined with those of Marco Polo, prepared the way for further developments.[1]

*Copernicus' Theory. The Earth a moving Ball.* At last (1473–1543), Copernicus came forward with the theory of the Earth's rotation once more, the same theory which had been dimly foreshadowed by Aristarchus so long before. Copernicus did not merely make statements, or revise what was already known ; he devoted his life to the proof of his theory, and to him falls the honour of being first to present this great truth to the world.

The theory of Copernicus taken in conjunction with the discovery of the laws of gravitation by Newton[2] and that of the law of centrifugal force by Huyghens formed a satisfactory basis for further investigations. It was now argued that, if the Earth were not revolving, the mutual attraction of all its parts would cause it to be a true sphere. But, if a spherical body, not sufficiently rigid, is rotating on an axis, deformation will result, as is seen in the case of clay on the potter's wheel ; the surface then tends to bulge outwards most the further it is from the axis, and consequently, at the equator.

*Newton's Theory. The Earth an oblate spheroid.* Newton (1642–1727) deduced in this way that the Earth must have the shape of an orange and is, therefore, a sphere-like body or spheroid, flattened at the poles, i. e. oblate. Richer's pendulum experiment, made about this time, was taken by Newton as a definite proof of the correctness of this theory. Richer found that a pendulum, which kept true time at Paris, lost two minutes at Cayenne near the equator. Newton showed this would naturally be the case if, at Cayenne, the pendulum is further from the Earth's centre than it is at Paris, seeing that a pendulum swings faster the nearer it is to the centre of the Earth.

Simultaneously with the announcement of Newton's discovery,

[1] A translation of Ptolemy's work into Latin by Angelus in 1410 also helped to revive interest.

[2] An excellent summary of the views previously held as to the Earth's shape is given by Varenius (died 1650) in his *General Geography*. This work was translated into Latin by Newton, 1672, for the use of students at Cambridge. An English version was published in London 1693.

two French astronomers named Cassini had, through errors in their measurements, arrived at the conclusion that the Earth was elongated like an egg ; hence, in France, Newton's ' orange ' became a ' lemon '. Thus arose a furious controversy, most amusingly parodied by Swift in *Gulliver's Travels*, where the Court was torn by factions between the Bigendians and Littlendians. Finally the French Academy settled the dispute in favour of Newton by sending expeditions both to Lapland and Ecuador. ' Thus ', grimly remarked Voltaire, ' (they) flattened both the poles and the Cassinis.'

*More 'pear' than 'orange'.* Newton's definition of the Earth's shape was so nearly true as to be universally adopted ; in fact for general purposes it still suffices.[1] The remarks on the subject in the early Victorian text-book, so comfortably arranged in question-and-answer form, began and ended with the statement : The Earth is an oblate spheroid. In 1875, however, Lowthian Green, inspired with the belief that the north and south polar regions were dissimilar in form and that there was also lateral flattening, adopted the view that the Earth's actual shape is due to the slight collapse of a pear-shaped body on cooling. Citing Fairbairn's experiments with cylindrical tubes, which clearly proved that a hollow cylinder, in cooling, became triangular in cross-section, Green thence concluded that a pear-shaped body under similar conditions would tend to assume the form of a tetrahedron. This supposition was strengthened by Lallemand, who, after exhausting the air very gradually from an india-rubber ball, found that the sphere took a somewhat tetrahedral shape (fig. 5).

If the tetrahedral theory were true, one would imagine that the main ridges on the Earth's surface were formed roughly about the same time, but when we consider the immense lapse of time that separated the principal geological movements, it seems impossible to accept any theory so simple. As, however, by its means, land and water seem to form a complete and

[1] The official value of the flattening of the Earth, as now accepted, is expressed as the fraction $\frac{1}{299}$, making the diameter of the Earth from pole to pole nearly 27 miles less than its diameter at the equator.

harmonious whole, each portion fitting like part of a puzzle into the place alloted to it, this subject will be again referred to later under ' The Surface of the Earth '.

More recent measurements, made in Antarctic regions and at the Cape, tend to strengthen the tetrahedral theory, by suggesting that the South Pole really is further from the Earth's centre than the North.

In 1903 Jeans calculated that the Earth probably is more pear- than orange-shaped, and there is some evidence to prove it is laterally compressed as well. The shape therefore is not

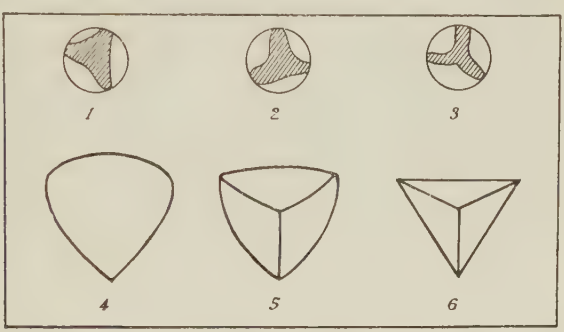



FIG. 5. 1, 2, and 3 show the collapse of cylindrical tubes on cooling as described in Fairbairn's experiments; 4, 5, and 6 show the possible stages in the collapse of a pear-shaped body on cooling. 4, a pear-shaped body; 5, a tetrahedron with curved sides; 6, a tetrahedron. (After W. L. Green.)

really spheroidal, but rather that of a badly-made peg-top with sides somewhat compressed, but not sufficiently so to make it even tetrahedroid. It has been agreed to call this form a geoid, so the final word on this subject is—to quote Sir John Herschel—' the Earth is earth-shaped '.

The actual deviations of the geoid from the sphere, and hence its exact form, can, as Sir George Stokes pointed out, ultimately be deduced from the variation of gravity over its surface, which can be determined by means of the pendulum.[1]

[1] Exact deductions on these lines are affected by the attraction of the parts of the Earth near to the observer. Thus, observations taken on oolitic limestone (sp. gr. 2) would give different results from those taken

A more recent theory to account for the form assumed by the Earth was put forward by Professor Love at the Leicester meeting of the British Association in 1907. Dealing, not with the ' geoid ', which is practically the shape the Earth would assume if covered by ocean, but with the form as seen if the oceans were drained away, Professor Love proceeded to show :

1. That the Earth's centre of gravity does not coincide with its actual centre.

2. That the Moon was once so much nearer the Earth that its attraction was great enough to produce actual deformation.

3. That these two influences were further affected by the Earth's rotation.

In propounding this dynamic theory to account for the Earth's shape, Professor Love pointed out how, on mathematical grounds, it explained the chief features of Land and Sea Distribution. This paper is very important and will be referred to again later.

In considering this subject we must, however, always bear in mind that the Earth's deviation from a sphere is extremely slight and the comparison with an orange or a pear involves great exaggeration. If a body, the shape of the Earth, were made about the size of a football and placed beside a true sphere, it is doubtful if the unaided eye would detect the difference.

*Modern accepted proofs as to the Earth's rotundity.* Having seen that, after centuries of speculation, the conclusion arrived at is that the Earth is practically a sphere, we now summarize the generally accepted proofs of this :

1. In eclipses of the Moon, the edge of the Earth's shadow upon the surface of the Moon is always seen to be circular. The only body which under all circumstances casts a circular shadow is a sphere.

2. All other heavenly bodies, in whatever position they are seen, appear to be circular, and the only bodies which appear circular in all positions are spheres. Therefore we conclude that they are spheres and that, by analogy, the Earth is probably a sphere also.

on basalt (sp. gr. about 2·8) which contained large deposits of iron ore (sp. gr. 5), and this fact would influence comparisons made in which the differences were exceedingly small.

3. The sea, or other large extent of water, affords an opportunity of observing the Earth's surface without the accidental irregularities of mountains and valleys. An observer, watching a ship disappear, first loses sight of the hull, and then of the masts. If the Earth were flat, the hull—being the more massive part—would be visible after the slender masts had disappeared.

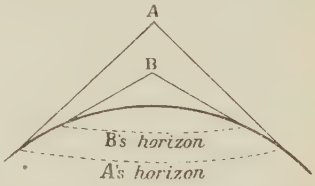



FIG. 6. Diagram to show that, owing to the Earth's curvature, observer A has a wider view than observer B, the horizon in A's position being further away than in B's.

4. The visible horizon at sea is always circular. This of itself is not a proof, for, even on a plane surface, the horizon would occur at the limit of vision and would therefore be a circle with that limit as radius. But a telescope, which increases the limit of vision, does not enlarge the horizon and, moreover, the horizon is more distant from the ' crow's-nest ' than from the deck of a vessel (fig. 6).

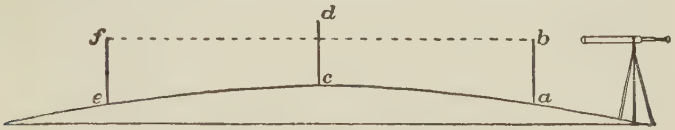



FIG. 7. Diagram of the Bedford Level experiment (much exaggerated). The three signal-posts being 3 miles apart from one another and the middle one projecting about 6 feet above the others, the Earth's curvature must be about 6 feet in 3 miles.

A landsman can use the same method by viewing the sea first from sea-level and then from a height. Thus, from the beach at Whitby, the sea seems like a narrow strip, whereas, from the ridge of Sleights Moor, overlooking Whitby, it appears as a high blue wall.

5. In 1870 an experiment to prove the Earth's rotundity was made by A. R. Wallace in the Bedford Level, and the same experiment was repeated by Mr. Yule Oldham on a six-mile stretch of water between Welney and Denver in 1900–1. In the Bedford Level experiment (fig. 7), three signals, each 13 ft.

4 in. above water-level, were erected at distances of three miles. On looking through a telescope, so adjusted that the line of sight just touched the tops of the first and last signal, it was found that the top of the middle signal projected more than 5 ft. above the others. In Mr. Oldham's experiment the middle mark stood up about 6 ft. above the others. It was estimated therefore that the Earth's curvature is about 6 ft. in three miles.

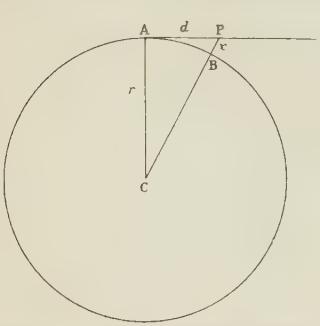



FIG. 8. To calculate the amount of the earth's curvature.

The amount of curvature[1] can be calculated as follows :

In fig. 8 let A be the point at which a levelling instrument is set and P the distant object sighted, AP being tangential to the Earth's surface at A.

The centre of the Earth is at C, and BP ($x$) is the height of P above the surface and is therefore the correction to be made in the distance AP ($d$).

Then CB and $r$ both being radii of the same circle :

$$CP^2 = CA^2 + AP^2, \text{ by Pythagoras' Theorem}$$
$$(r+x)^2 = r^2 + d^2$$
$$\therefore\ 2rx + x^2 = d^2, \text{ subtracting } r^2 \text{ from each side}$$
$$x(2r+x) = d^2$$
$$x = \frac{d^2}{2r+x}$$

But $x$ is so very small in comparison with $2r$ that we may neglect it and write the equation :

$$x = \frac{d^2}{2r} \text{ or } \frac{d^2}{7{,}916} \text{ miles.}$$

It will be seen that if $d$ is 1 mile, the correction is $\frac{1}{7916}$ of a mile, or about 8 inches, i. e. $\frac{2}{3}$ ft.

If $d$ is 2 miles the correction is $\frac{4}{7916}$ miles or $\frac{2}{3}$ ft. $\times 2^2$, i. e. about 32 inches, or simply

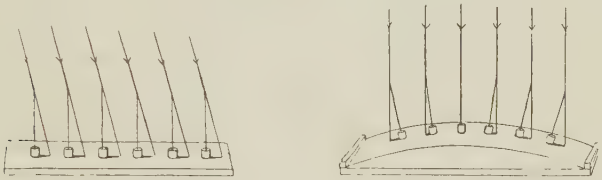
*Correction in feet for curvature is* $\frac{2}{3} \times$ (*distance in miles*)$^2$.

6. The Sun or the stars viewed at the same time from different stations on the Earth's surface have different altitudes.

[1] Engineers in canal and road making avoid the difficulty of curvature by putting the level equidistant between two points and sighting both ways. The errors of curvature, being equal in opposite directions from the instrument, are thus eliminated.

These heavenly bodies are so distant that the rays from them to all parts of the Earth are practically parallel, and therefore this visible difference of altitude must be due to the curvature of the Earth's surface.

*Class-room experiment.* The following experimental illustration will make this clear: Take a board about 4 feet long and 6 inches wide and thin enough to bend slightly. Glue to it at intervals five or six small cotton-reels (fig. 9*a*), into the holes of which are glued pieces of pencils, making upright styles or gnomons about 8 inches high, all exactly equal in height. Mark the board plainly in inches. Place it so that the direct rays of the Sun, or of a lantern sending an approximately parallel beam, cast shadows of convenient length on the board. (An acetylene cycle lamp is excellent for class-room work.)



*a* *b*

FIG. 9. Showing effect of Earth's curvature on altitude. *a* shows that if the Earth were flat the altitude of a heavenly body would be constant in all parts of the Earth. *b* shows that if the Earth is curved the same heavenly body appears to be at different altitudes in different parts of the Earth. (Experiment devised by Mr. J. A. McMichael, H.M.I.)

It will be seen that these equal gnomons cast equal shadows. This represents what would occur if the earth were flat, i. e. the altitude of a heavenly body would be constant in all parts of the Earth.

Take another and thicker board of the same size (fig. 9*b*), but nail across the ends of it pieces of wood 1 inch square and 6 inches long, to act as stops. Bend the first board so that it is held in a curved position by means of the stops.

When this is placed in the path of parallel rays of light, the lengths of the shadows will vary, and if it is so placed that one of the centre gnomons casts little or no shadow, those on one side will cast shadows in one direction and those on the other side in the opposite direction. This now represents what is seen on a curved Earth, and we have a representation of the short shadow and high altitude of the Sun within the tropics and of the lengthening shadow towards the poles.

## II. The Size of the Earth

*Earliest measurements.* The first estimate of the Earth's circumference is generally ascribed to the Chaldaeans and undoubtedly the measurement of certain parts of it originated in the great river-valleys of Egypt and Mesopotamia. Here all landmarks being periodically swept away by the rising waters, the owner of land, in order to reclaim his lawful possessions, had to present some proof of their extent.[1] This however does not seem to have led to any general application of the methods used, so although Herodotus, probably with truth, claims for the Egyptians the invention of geometry, yet its origin as a science really falls to the credit of his own countrymen. The use of geometry was evidently a matter of discussion in Athens in very early days, when the Greeks still believed that the Earth was flat and consequently that there was only its circumference to measure. Thus, the famous comic poet and dramatist Aristophanes (born 427 B. C.), mocking at the philosophers of the day in *The Clouds*, represents the walls of the ' Reflectory ' or ' Thinking-shop ' of Socrates as hung with geometrical instruments, intended for the measurement of the Earth.[2]

*Aristotle's statement.* Aristotle mentions that its circumference had been computed as 400,000 stadia or 40,000 geographical miles, and this statement, though incorrect, shows that observations had already been made. The means employed for measuring were similar to those used by Eratosthenes, whose name should be remembered for all time, he being the first to obtain an approximately true result.

*The Method of Eratosthenes.* The method resorted to by Eratosthenes was the following: he noticed that at Syene

[1] A plan representing a plot of land, measured in cubits, is seen among the Babylonian inscriptions on tablets in the British Museum, also the eye-piece of a surveying instrument from the Nile valley.

[2] See translation of *The Clouds*, by Starkie, p. 55. ' Geometry ? And what 's its use ? ' ' To make a survey of the Earth.' ' You mean the allotment land ? ' ' No, but the whole Earth.' ' A charming idea that—both democratic and serviceable.'

(Aswan), on a certain day, the Sun's rays penetrated to the bottom of a deep well, and he, therefore, concluded that the sun was directly overhead. At the same time at Alexandria, the sun was one-fiftieth of a circle's circumference from the zenith; therefore the distance from Syene to Alexandria, measured on the Earth's surface, would be one-fiftieth of the Earth's circumference. This distance proved to be 5,000 stadia, so that the Earth's circumference must be 250,000 stadia, which is equal to 25,000 geographical miles (according to one of the suggested values of a stadium). The true circumference is 24,899 miles, so that the results obtained were much nearer the truth than would be expected from such an experiment; the errors in the measurements probably balanced each other. The idea of using two fundamental lines, at right angles to each other, as a basis for the determination of position, originated with Eratosthenes, so we owe to him also the idea of latitude and longitude.

*Hipparchus divides the circle.* Hipparchus followed Eratosthenes in drawing a system of parallels, and he, for the first time, made the division of the circle into 360 degrees.[1]

*Strabo's contribution.* Progress in this direction came but slowly. Nearly two centuries later Strabo (64 B. C.–24 A. D.) followed Eratosthenes in method, but calculated the Earth as being somewhat smaller. In his maps, which claimed to show the whole habitable globe, *length* is always reckoned from east to west.

*Ptolemy and after.* Ptolemy (about A. D. 150) resorted once more to the method of Eratosthenes and Hipparchus, in using two lines at right angles as a basis of determination; he also adopted the division of the circle into 360 degrees. Assuming that a degree of longitude was always the same length, i. e. 500 stadia or 50 geographical miles, if he found that two places were said to be 500 stadia apart, he called their distance one degree,

[1] The mode in which the division of the circle first arose is not clearly known. In very early days, the Chinese divided it into $365\frac{1}{4}$ degrees, so that the Sun in one day passed through a degree. Perhaps the number 360 was founded on that.

without verifying it. This affected, very disadvantageously, the accuracy of his map and measurements, for the ' length of the oikoumene ', i. e. the distance east and west of the habitable Earth, appeared nearly one-third greater than it really is and so the computed distance between Spain and China by water was diminished by about 2,500 miles[1] (fig. 10).

After a lapse of time, only partially bridged by the researches of the Arabs,[2] the scientists of the twelfth century seem, somehow,

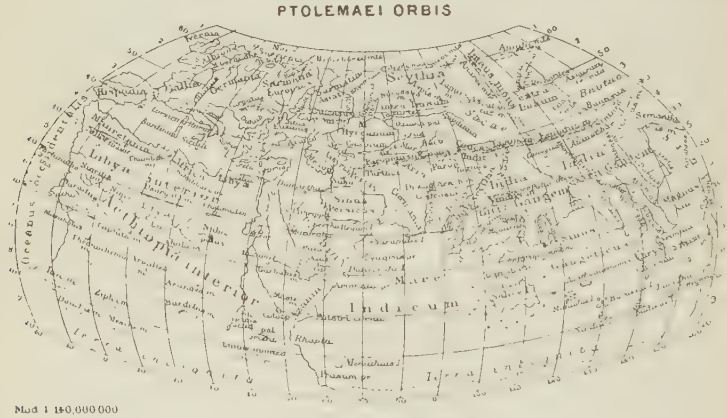



Fig. 10. Ptolemy's Map.

to have attained a very fair knowledge of the size of the Earth and the length of a degree. Tables of latitude and longitude were drawn up, and partly on these, but partly also on new calculations, were based the Alfonsine Tables, named after Alfonso X (1252–84).

*Roger Bacon's estimate.* In the thirteenth century Roger Bacon (1214–94), taking about 57 miles[3] as the length of a degree

[1] One argument early used in proof of the narrowness of the sea between West Africa and East Asia was based on the occurrence of elephants in both regions.

[2] Caliph Abdullah Al-Mamûn (A. D. 814) caused a certain length of the Earth's surface to be measured with rods.

[3] Bacon's miles contained 1,000 cubits or 6,000 feet, and therefore 57 Baconian miles were approximately equal to 65 English miles. He

of longitude at the equator, calculated the Earth's circumference, making it very little less than it really is. The fact that longitude could be made out by knowing the difference in time between two places was recognized as early as the thirteenth century.[1] Increased opportunities for obtaining knowledge were not followed up in the early Middle Ages, and Ptolemy's work, which had been neglected by his immediate followers and for long after, now began to be revived, his map and estimate of the Earth's size being generally accepted.

*Marco Polo's journeys and Toscanelli's map.* The remarkable experiences of Marco Polo and his minute descriptions of China and Japan tended still further to magnify the supposed width of Asia, already exaggerated by Ptolemy. For this reason, the map handed by Toscanelli (fig. 11) to Columbus and on which he faithfully relied throughout his career, being based on that of Ptolemy and embodying in it the corrections of Marco Polo (about 1399), gave an even more optimistic view of the chances of reaching India westwards than Ptolemy's would have given.

*Primitive methods of sixteenth century.* As time went on the most primitive methods of measurement still prevailed; for instance, about 1524, Fernel, a physician at the French court, estimated what place would be exactly a degree north of Paris and, starting from that place, measured the distance back to Paris by counting the revolutions of a wheel. Thus he hoped to fix the length of a degree in miles on the Earth's surface.

*Triangulation first attempted (seventeenth century).* Not till 1615 was the idea of obtaining distances more accurately by triangulation first attempted by Snell, a Dutchman, who carried out a series of measurements on the frozen fields round Leyden. This experiment did not at once inaugurate better methods, for, in 1637, Richard Norwood, in England, calculated the

made the Earth's diameter 6,500 miles (see *Opus Maius*, edited Bridges, 1897, pp. 224–6).

[1] This led to no practical result until the perfection of the chronometer by Harrison in 1765 and of the sextant by Hadley in 1731.

length of a degree partly by pacing the distance from London to York and partly by measuring it with a chain. His results were published in *The Seaman's Practice.*

*The Telescope first applied.* The first really accurate measurements were made by Picard, as late as 1669, at the court of Louis XIV, who took a great interest in scientific advancement. No one, previously, had thought of using the recently invented telescope for purposes of measurement, but Picard measured the

FIG. 11. Toscanelli's Map of the Western Ocean, 1474, which was known to Columbus.

angles of his triangles by means of a quadrant, fitted with a telescope with cross-wires. This marked a very great advance in accuracy. When Richer's observations with the pendulum led to Newton's announcement of the fact that the Earth was oblate or flattened at the poles, it was soon realized that still more careful measurements must be made. Hence in 1783 the measurement by triangulation of Great Britain was begun under General Roy, theodolites being used for the purpose.

*Exact measurement depends on exact shape being known.* The computation of the exact size of the Earth depends really on our knowledge of the actual form of the geoid, to discover which

a vast number of researches must be made. In the nineteenth century this exact shape became a matter of almost universal interest and speculation, as instanced by the fact that in 1862 an International Geodetic Association was inaugurated, mainly with the view of elucidating this problem. The ways in which clearer notions of the shape were gradually formed have been traced under the heading ' The Shape of the Earth ' and need not be repeated. Suffice it to mention that Sir George Stokes of Cambridge proved that the shape of the geoid can be inferred from the variations of gravity over its surface, these variations being determinable by means of a pendulum (see note above, p. 25). Before the exact shape and, hence, the exact size can be accurately stated, more data must be obtained, especially in Antarctic regions. The actual method which must be employed for this purpose will be to find the position of two places by observatory methods and the distance between them by survey methods. When this is done all over the Earth, as accurately as possible, we shall possess practically all the necessary information of the most reliable kind. The degree of accuracy thus attained is indicated by the following data, which form part of a table of values obtained by the above methods :

Length of a degree of latitude in lat. 0°, 362,748 ft.
,, ,, ,, 10°, 362,858 ,,
,, ,, ,, 20°, 363,174 ,,

For ordinary purposes, however, we may consider the Earth as a sphere, with a diameter of, roughly, 8,000 miles and a circumference of 25,000 ; that is, we may be satisfied with the computation of the ancient Greek philosopher Eratosthenes, which computation was made about 200 years before Christ.

## III. The Earth's Origin and Structure

*Ancient ideas as to the Earth's origin.* Ancient ideas with regard to the Earth's origin belong to the realm of philosophy rather than science. The philosophers had no system for interpreting the facts of nature, but usually adopted a method wholly speculative. The interest to us of their beliefs is, however, very great, for, so widespread are some of them, that they must either have crept in some mysterious way round the world or else the same appearance stimulated the same train of thought in widely diverse minds.

One of these extraordinarily universal beliefs is that of the 'world-egg', which appears as a conception in parts of the Earth wholly remote from one another.

The earth-egg of the Norseman was laid by a gigantic stork-like bird.

In Egypt, the world-egg emerged out of watery chaos and, splitting in two, formed both heaven and earth.

In Phoenicia, the egg was the offspring of the god of the rising sun and of night or chaos.

The Hindu god Brahma, seated in meditation throughout long ages, at last produced an egg of gold as large as the Universe, out of which the latter was slowly evolved.

The roc's egg in the 'Story of Sindbad the Sailor' in the famous *Arabian Nights' Entertainments* is a dim reflection of the same belief.

The remote inhabitants of Polynesia still have a tradition that the god of the heaven and the atmosphere, hovering as a bird over the ocean-waters, laid an egg—the world-egg.

In all these quaint theories the idea of the egg plays its part, and one wonders, not so much how it arose, as how it became common to peoples totally unknown to one another.

*The centre of the Universe.* All through ancient times and the Middle Ages, first the Earth and then the Sun was accepted as the centre of a spherical Universe, but no theory as to the origin of this Universe seems to have been established. In fact

nothing could really be done towards the discovery of the Earth's origin until after the invention of the telescope.

It seems to have dawned on Kepler first that possibly the Sun might not be the centre of the whole Universe, but merely a star amongst others.

*Development of the nebular hypothesis.* Following Kepler, Sir William Herschel pointed out that, as well as the stars, a vast number of cloudy masses could be seen in the heavens at night. He believed that these masses were clusters of stars in process of formation and suggested that stars probably resulted from the condensation of vapour, just as steam, greatly condensed, becomes ice. This idea developed later into the 'Nebular Hypothesis', and although in this case, as in many others, we are probably still standing on the threshold of sure knowledge, yet we may honour Kant and Laplace as having contributed the corner-stone of the building yet to be. To understand this theory it is simplest first to follow in thought an experiment performed by a French physicist. M. Plateau, by adding oil to water and then mixing a little alcohol with it, found that the oil formed a globe, which remained freely suspended in the mixture. He then proceeded to whirl the glass vessel and its contents rapidly round and round. The globe of oil first became flattened at its poles and spread out at its equator—just as does soft clay on the potter's wheel—then it proceeded to throw out little globes from its equatorial part, these also continuing to rotate and also to revolve round the parent globe. Thus Plateau manufactured a miniature solar system and proved that the forces controlling matter could, under certain circumstances, produce, quite naturally, such an arrangement.

Kant's *Cosmogony*, appearing in 1775, contained the suggestion that the Solar System had been originally a vast nebula or vapoury mass, extending from the Sun as centre to beyond the path of the furthest planet. Laplace, in his *Système du Monde*, further explained how this great hot cloud, revolving, threw off whole rings or fragments of its edge, which would gradually collect together into rounded masses. In the end, the original nebula would be replaced by a series of more or less

compact bodies, all revolving round a central mass, perhaps still nebulous, each of these bodies retaining its original spinning motion. That a large number of existing nebulae appear spiral in structure was discovered later by means of the telescope (fig. 12).

Kant based his theory on metaphysical reasoning; Laplace built up his on mathematical investigation; it remained for Herschel, as mentioned above, to supply the astronomical observations. To this end he devoted his life, discovering the existence in the heavens of a large number of nebulae, and thus the great theory was fully launched. Discoveries, since made, have contributed on the whole to strengthen it, although in some ways it may need modification. The various nebulae, now well known in the heavens, are objects of interest carefully watched, seeing that they may represent stages in the development of systems like our own. It is even possible to conceive of the existence of nebulae on a grander scale than these, as it has been suggested that the Milky Way itself may be a vast nebula, extending far beyond the range of observation of our most powerful telescopes.

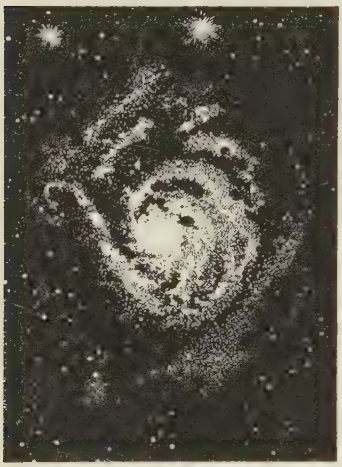


FIG. 12. Drawing taken from a photograph of a spiral nebula in Ursa Major. (After Chamberlin and Salisbury.)

Although the Laplacian hypothesis has done so much to help us to a conception of the Solar System's origin, yet, in the light of modern science, certain considerations come into play which render necessary some modification of its teaching. The hypothesis, as originally conceived, presupposed that all nebulae were in a gaseous state; certain of the known nebulae seem to agree with this supposition, but by far the larger number do not.

Perhaps the most important difficulties that have been raised against the theory of a gaseous state are:

1. That a vast spheroid of gaseous matter shrinking gradually and continuously through loss of heat would not 'throw off' separate rings of matter, as the theory states, but the main mass, drawing away from its equatorial part, would leave this as a continuous disc. We could not get a formation like that of the Solar System, which shows rhythmic development, unless the equatorial matter separated off by particles rather than by rings.

2. According to the laws of the relations of mass and momentum, the whole moment of momentum of the Solar System would not enable it to detach a planet so remote as Neptune; in fact, until it had contracted well within the orbit of the nearest planet, its rate of rotation would not be sufficiently great for it to detach planets at all.

3. Annular nebulae, which show evidence of successively developed rings, are unknown, and yet it is hardly conceivable that no planetal systems in process of formation should exist; on the other hand, spiral nebulae abound and require explanation.

4. Another peculiarity of most nebulae is that they give a continuous spectrum, which is characteristic of matter in the liquid or solid but not in the gaseous state.

The nebular hypothesis, however, does not stand or fall owing to the limited interpretation given to it by its great progenitors. Although the theory of the gaseous nature of the nebula presents insuperable difficulties to the modern physicist, yet the hypothesis as a whole is capable of expansion and adaptation, and alternative views have been proposed.

*Meteoritic hypothesis.* Lockyer sought to evade some difficulties by supposing the nebula to consist of a swarm of meteorites, which might be liquid or solid in substance, but which, owing to collision, would in part resume the gaseous state. The luminosity of the nebulae would be thus explained, as collisions would be frequent, but it would seem most difficult to suppose that meteorites would move in one plane, also their composition is unlike that of the planets and their structure cannot be accounted for by this mode of origin.

Sir George Darwin, working on this hypothesis, proved that the behaviour of a swarm of meteorites would, in effect, be that

of a coarse gas, and consequently a meteoritic nebula would obey the same laws as an entirely gaseous nebula.

This hypothesis does not then seem to offer any further elucidation of the problem.

*Planetesimal hypothesis.* Chamberlin rejected Lockyer's proposition as inadequate and approached the question from an entirely different standpoint. Now that we know, he argued, most nebulae to be spiral in structure, it seems as if, by a very close observation of the various forms of spiral nebulae, it might be possible to trace their development at different stages and so to discover whether, in the course of it, they were likely to assume a form similar to that of a solar system. This has been done with great success, and the series of photographs produced in Chamberlin's work supplies a very strong argument for the development of the Solar System from a spiral nebula. Far from this being at variance with the Laplacian hypothesis, we find agreement can be arrived at simply by adopting the view that the nebular material is not gaseous, in the main, but rather solid or liquid.

The planetesimal theory of Chamberlin supposes the nebula to consist of small liquid or solid particles, thus explaining the continuous spectrum. The aggregation of such particles might take place in various ways, but that suggested by Chamberlin is the approach of two bodies to one another. If we call the larger body the Sun, long protuberances, like those seen on the Sun during an eclipse, would be generated from it, one shooting out towards the approaching body and the other on the opposite side of the Sun, i. e. away from the other body. Both of these, attracted by the approaching body, would tend to curve towards it in the direction of its movement. They would appear as two great whirling arms, loosely concentric, but diverging outwards from the central, more quickly revolving mass and losing speed as they go.

It is not necessary to suppose that these protuberances burst out all at once: they probably represent a series of explosions. Hence, in their swift whirling they tend to become knotted and the knots have a like motion. The series of photographs displayed

in Chamberlin's work shows the invariable presence of the whirling arms, the disc-like shape of the nebula, various stages in the formation of the knots, and their separation from the main mass. The central mass being the Sun, each knot is the nucleus of a future planet, and the remaining material, attracted by the planet-nucleus nearest to it, would contribute to its final substance. This theory does not quite explain the luminosity of the nebula, but so much has been contributed lately to our knowledge of the ultimate structure of matter, that it seems likely this difficulty may vanish. In any case, this view tends to dispel many objections urged against the nebular hypothesis as at first stated.

*Later discoveries.* Further investigations as to the origin of the Solar System, which have recently been carried on, seem to follow on the lines of Chamberlin's theory—

1. in the immediate cause of the formation being due to the approach of an outside body,

2. in the supposition that the body on its approach causes the formation of protuberances.

In an article recently published, Jeffreys explains his own investigations and those of Jeans, which appeared in 1917, 1918, and 1919. He shows that the Earth, in order to form as a planet at all, cannot have had a specific gravity less than $\frac{1}{5}$ of what it is at present, otherwise it would have been dissipated into space. This density would necessitate a mass of matter near the Sun so enormous that its disappearance from the present Solar System could not be explained; it is therefore only possible to suppose that the condensation took place in a limited portion of the Solar System, and was such as might form from a filament projecting from the Sun and not from a mass surrounding it. Jeans has explained that a filament of this kind would result from the approach to the Sun of a star of greater mass than the Sun itself. The Sun's envelope would then first assume an egg-shaped form, with the point projecting towards the star. As the latter approached, the point would become a gap and the gaseous substance of the Sun would emerge, at first slowly, then more rapidly, then slowly again as the star receded. The

filament thus produced would be thickest in the middle and would revolve round the Sun in the plane of the star's orbit. A body so tenuous would soon become broken up, and thus the planets would result, the larger ones at a medium distance from the Sun where the filament was thickest.

This theory accounts not only for the planets themselves, but explains also other phenomena connected with the Solar System, such as the asteroids, some of the satellites, the zodiacal light, &c.[1]

*Structure of the Earth.* The stages passed through by the consolidating globe, before it became suitable for man's habitation, do not really concern the geographer, who has to deal with its superficial aspect only. Some knowledge of the Earth's internal structure is, however, required to account for the phenomena of vulcanicity, &c. The early idea that the Earth consisted of a solid shell, enclosing a fiery central mass, was founded on the knowledge of the intense heat of volcanoes. Newton, however, estimated that the Earth's weight as a whole must be quite twice as great as it would be if it consisted throughout of the same rocks as at the surface, and this would support the view of its being solid throughout. Later physicists, notably Lord Kelvin, have pointed out that the Earth must have the rigidity of steel, as otherwise it might suffer deformation owing to tides. Some still believe that a liquid substratum exists immediately beneath the crust, but it seems more in agreement with known facts to accept this only as a potentially liquid layer, held in the solid state by pressure, so that if, locally, pressure is removed, the material may emerge as a liquid. The fact of the Earth's internal heat is in accordance with its nebular origin, either as a gaseous mass, which has cooled from without, or as a mass of minute planetesimals which, by being welded together by shrinkage, produced heat. The latter theory would explain the fact that the central nucleus consists of heavier material, for, as the nucleus of the planet increased, its power of taking up material increased also and, orbital collisions becoming

[1] For references to the original papers see the magazine, *Discovery*, No. 5, May 1920.

more frequent, the lighter materials, which had at first escaped, were finally captured.

Having considered the above facts and theories we nevertheless realize that, for practical purposes in geography, the Earth may be regarded as a solid globe ; we must not, however, forget that, in structure and origin, our Planet is a member of the Solar System and acts in strict obedience to its laws.

## IV. The Earth's Relation to the Sun

*The Earth's dependence on the Sun.* As already shown, the Earth is a member of the Solar System and obeys the laws of that system. A closer inquiry into these shows that the Earth, as a dwelling-place for all known forms of life, is entirely dependent on its source of origin, the Sun. We have only to imagine the Earth as floating freely in the Universe, cast off by the Sun, to realize that it would be an entirely dead world. Day would no longer succeed the endless reign of night; summer would never come to soften the rigours of an eternal winter ; no rain would descend to cause springs to flow into rivers, or to help the rocky surface to crumble into soil ; green plants would not exist, and few, if any, others. Animals would practically cease to be, seeing that, without plants, land-animals could not survive, and, if the sea remained available for life, it is doubtful if even deep-sea forms are wholly independent of warmth.

In fact, the Earth's dependence on the Sun is absolute, even so transitory a phase as an eclipse suspending for the time being the ordinary routine of nature.

The Sun is the centre and origin of the Earth's light and heat, although so small in comparison and so distant is the Earth that it absorbs only $\frac{1}{2.000.000.000}$ of the radiant energy the Sun has to bestow. This seemingly small amount suffices to vitalize every living form and to supply energy for all work, so that, if we could look upon the Earth as a mighty machine, of which every living thing forms a part, the Sun would be the

power that set the vast fabric in motion and maintains it at full working capacity throughout the ages.

*The length of the year.* The supposed movement of the Sun round the Earth (which is in reality a movement of the Earth round the Sun)[1] fixed, in the earliest times, the length of the year. It was known that one revolution took about $365\frac{1}{4}$ days, but, for convenience, the year was counted as 365 days long.

In 45 B.C. Julius Caesar rectified the absence of about a quarter of a day in each year by introducing an extra day in every fourth year. The result was known as the Julian Calendar. Owing, however, to the year being rather less than $365\frac{1}{4}$ days long (actually 365 days 5 hrs. 48 min. 46 sec.), the calendar was 10 days out when, in A.D. 1582, the three century Leap years in the next 400 years were made ordinary years. This method was adopted by the Roman Church, but not by the Greek Church, hence the use of the 'Old Style' still in Russia. When, in 1752, the 'New Style', as it was called, was introduced in England, the error had mounted up to eleven days. These eleven days were cut out of that year and, to avoid the error in future, it was agreed that the century should only be counted as Leap year when the number was divisible by 400; thus 1900 was not a Leap year although divisible by 4. A few of the old days are still remembered with us, as, for instance, Old Christmas Day.

*Alternation of day and night.* If the Earth is a globe revolving round the Sun, and if that is its only movement, obviously one side of the ball will be always in the light and the other in the dark, because the Sun's rays cannot shine on more than half of the surface. If, however, the Earth rotates on its axis, the light and heat are received on all sides successively, and thus the alternation of day and night is established. Various demonstrations are necessary to bring these facts home to children. The

[1] Throughout this chapter models must be used to illustrate the various points. For these are required: (1) two balls representing Sun and Earth respectively; (2) a knitting needle to represent the Earth's axis; (3) a pin to show position of spectator on the Earth; (4) the signs of the Zodiac can be drawn roughly or painted in white on a strip of brown paper and placed on the table surrounding the two balls, so that the Sun, as seen from the Earth, passes near first one, then another, according to the season.

two simultaneous movements are made clear by making a child waltz round the room; the child (the Earth) rotates several times in one revolution and is seen to turn the face and back alternately to any one (the Sun) standing near the middle of the room. A drilling exercise shows that a rotating body moves much more quickly at the circumference than at the centre, for, in wheeling, the outer members of the class have to take long steps to get round, whereas the innermost one remains on the same spot. Further, with a spinning-top, we can show the existence of an axis and that the axis of the top as it spins is often not erect but inclined. Then, taking two balls, one to represent the Sun and the other the Earth, it is easy to show day and night as being always of equal length, i. e. 12 hours each, so long as the axis is at right angles to the plane in which the ball, representing the Earth, rotates.[1]

*Alternation of the Seasons.* As shown below (p. 55), the amount of heat received by the Earth depends on the direction in which the rays fall, and therefore, with an axis at right angles to the plane of rotation, there will be no change of seasons, and at 12 o'clock the Sun will always be at the same height in the sky, so long as we remain at the same place.[2] The Sun being always overhead at the equator, the amount of heat received in each part will be the same all the year round and equivalent to the amount now received at the equinoxes. Thus, in England we should have perpetual spring, whereas at the equator the intense heat of summer would prevail throughout the year. The whole economy of Nature outside the tropics[3] is, however, adapted

[1] To make the position of the axis clear, a hatpin is put through the Earth-ball, projecting at each pole.

The limit to which the Sun's rays can reach is further emphasized by cutting a hole, the size of the ball, in a piece of paper and holding the paper vertically so as to show where the limit of illumination comes, or by holding long knitting-needles to represent rays, so as to show where they can and cannot touch the Earth.

[2] For a good account of the Seasons, with diagrams, see *Physiography*, T. H. Huxley and R. A. Gregory. Macmillan & Co., London, 1904, pp. 375 et seq.

[3] A Javanese boy, in England for the first time, wondered what was the matter with the trees in autumn and tested one with his knife to see if it was alive.

to a change of seasons, and evidence shows that the same has prevailed in geological times. The inclination of the axis, which causes this alternation of seasons, is $23\frac{1}{2}°$ in amount and the axis points almost exactly towards the Pole star or, more accurately, describes a tiny circle round it.

As the term ' equinox ' indicates, there is a time in the year when days and nights are equal in length, the Sun being then overhead at the equator. By using again the Earth-ball, holding it with its axis inclined and pointing always in the same direction, we see that, as it revolves round the Sun-ball, there are two separate periods in the circuit or year, occurring opposite each other, when this condition obtains. When the Sun is exactly overhead at the equator, the angle of incidence of its rays produces with us either spring or autumn, as it does also in all places at an equal distance from the equator on the opposite side. As a matter of fact, in olden times the year began at the spring or vernal equinox, this custom being still preserved in the names of the months from September, the seventh month, to December, the tenth month. This way of counting the months is still used in France. In March, at the year's beginning, the Sun appears, from the Earth, to move near the constellation of Aries, the Ram, therefore the old rhyme of the Signs of the Zodiac begins with the Ram :

> The Ram, the Bull, the Heavenly Twins,
> And next the Crab, the Lion shines ;
> The Virgin and the Scales,
> The Scorpion, Archer, and the Goat,
> The Man who bears the watering-pot,
> The Fish with glittering tails.

As the Sun passes northward, half-way between the equinoxes, it reaches the most northerly point, $23\frac{1}{2}°$ north of the equator. It then appears as if near the constellation of Cancer, the Crab, so the parallel of latitude at which the Sun seems to take a southward course again is called the ' tropic of Cancer '. When the Sun crosses the equator again, it is in the constellation of Libra, the Scales, and this is the autumn equinox; finally, when the Sun appears near Capricornus, the Goat, the ' tropic of

Capricorn ' is said to be reached. In all these cases the Sun's apparent movement is mentioned instead of the Earth's actual movement.

At midsummer, in the northern hemisphere, a glance at the model shows that the Earth's axis is tilted towards the Sun, so that the rays of the Sun extend not only as far as the pole, but $23\frac{1}{2}^{\circ}$ beyond it. The result is that a small part of the Earth's surface, of which the north pole is the centre, is on the side of the Earth turned towards the Sun during the whole rotation and never enters the shadow at all. During this time the days within the Arctic circle are twenty-four hours long. In very early days the Northmen were familiar with the ' midnight sun ', and the wonder of it was probably brought to Britain about the time of Alfred. Thus, Othere, the old sea-captain, describing his adventures in the north, is represented as saying : [1]

Round in a fiery ring
Went the red sun, O king.

The same conditions prevail when the Earth reaches the opposite side of the Sun, so that the latter is overhead at the southern tropic. Sunshine then floods the whole Antarctic area and a corresponding period of darkness and cold obtains in the north. During the winter, in either Arctic or Antarctic region, the Sun never comes above the horizon and, in our latitudes, the days get shorter until the shortest day is reached.

When the Earth is in this position with regard to the Sun, the latter appears, for a few days, to stand still before beginning once more to approach the equator ; this is called the summer or winter solstice.

*The Zones of the Earth.* It will be seen that the tropics, forming the limit to where the Sun can be actually overhead at midday, and the Arctic and Antarctic circles, as marking the limits of the twenty-four-hour days and nights, are convenient divisions of the Earth's surface, being fixed by the inclination of the axis.

Using these as boundary lines, the Earth has, therefore, been

[1] See Longfellow.

divided into five zones or girdles. The limits of the zones are accordingly $23\frac{1}{2}°$ and $66\frac{1}{2}°$ north and south respectively.[1]

These zones will be more fully referred to under 'Climate'.

The names of the zones (fig. 13) are derived from their difference in heat, but as they are actually distinguished from one another by the amount of the Sun's rays they receive, they are really

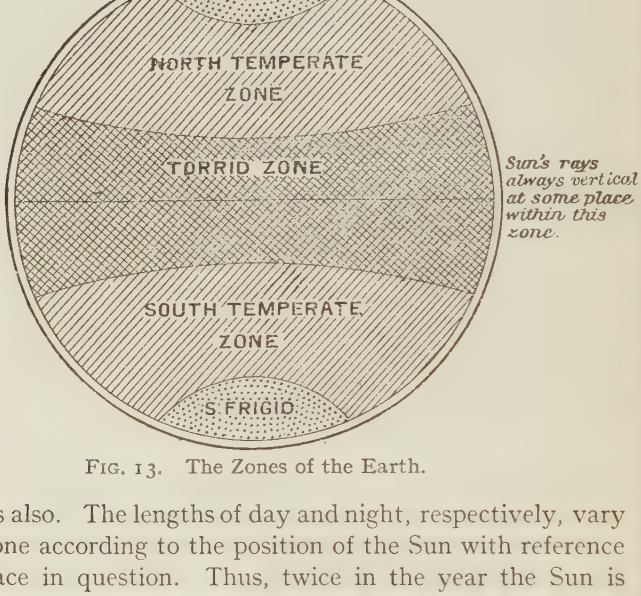



FIG. 13. The Zones of the Earth.

light zones also. The lengths of day and night, respectively, vary in each zone according to the position of the Sun with reference to the place in question. Thus, twice in the year the Sun is overhead to every place within the tropics, but it is never over-

[1] The symbol °, meaning a degree, is used in more than one sense, as is also the word 'degree' itself. In the expression $23\frac{1}{2}°$ a degree of arc is meant. This is the measurement on the circumference of any circle of the angle enclosed by two straight lines proceeding from the centre, the distance being $\frac{1}{360}$ of the circumference. The geographical degree has the same meaning, but does not coincide with this because the Earth is not a true sphere. The word and symbol used in connexion with temperature are quite distinct in meaning from this, though the use of the term 'degree' is probably due to the fact that the tubes of the earliest thermometers were bent in a circle.

head to any place outside them. As we go north or south of the tropics the possible length of day increases, for at the equator it can never exceed 12 hours; at about the latitude of London the longest day is nearly 17 hours. Within the Arctic or Antarctic circles, though daylight lasts 186 days in summer, the Sun never rises higher than $23\frac{1}{2}^\circ$ above the horizon and the oblique rays, in passing through the atmosphere, lose so much radiant energy that great heat is never attained. Within the tropics, however, where the Sun's altitude is so much greater, and consequently the rays come nearly or quite vertically through the atmosphere, very great heat is experienced. At the tropics the longest day is $1\frac{1}{2}$ hours longer than at the equator, and so the actual amount of heat received there at the summer solstice is greater.

The zones of different insolation, mentioned above as resulting directly from the relations of the Earth and Sun, make up what is called the mathematical or insolation climate. This would be regular and unvarying if other causes and effects were not so disturbing. As it is, however, the atmosphere plays such an important part in overthrowing all rules, that it is necessary to go into the matter more fully under the heading of 'The Atmosphere'.

# SECTION II. THE ATMOSPHERE

## V. General Account

*Extent and appearance of atmosphere.* We live at the bottom of an ocean of air, just as deep-sea animals live at the bottom of an ocean of water, but our air-ocean is deeper and our bodies are accordingly adapted to the conditions of what might be called deep-air organisms. This air-ocean encloses the globe in a gaseous envelope extending outwards for a distance of at least 100 miles. We have not, so far, been able to explore its depths, or heights, beyond about 7 or 8 miles, so the supposition as to its extent is based on the fact that meteors flash into brightness when they come within that distance of the Earth's solid surface and must therefore meet some substance which gives rise to friction. One great difference between the air- and water-oceans is that air is exceedingly elastic and compressible, so that whereas the lower layers are closely compressed by the weight of those above, yet, away from the Earth, its substance probably becomes less and less, until it is reduced to a condition of extreme tenuity. In shallow layers air, like water, appears transparent and colourless and fills every space with an impalpable fluid. We can detect its presence by movement, for something then always offers resistance. Something also can be seen by looking into the depths of the atmosphere on a clear day, for it has the appearance of a vast blue dome. The ancients believed in the actual existence of this dome, and in the Middle Ages it was regarded as the hollow sphere on which all the fixed stars were hung. The blue colour is, probably, mainly due to the fact that the Sun's light rays are broken up by the tiny dust motes floating in the air, just as a prism breaks up and bends the rays. The short blue rays are scattered by this means, and show up against what would otherwise be the black background of space. Often, in temperate regions, the blue is curtained off by masses

of water-particles, which hang near the Earth's surface and are called clouds. These affect the Sun's rays also, so that at sunset, when the rays come slanting through a greater thickness of atmosphere, brilliant colour effects are often produced, red predominating because the longer light-waves get through more easily.

*Composition of atmosphere.* The atmosphere consists entirely of gases, with the exception of water-particles, which are often present but in very varying quantities, and a certain small amount of solid matter. The presence of this last is usually disregarded in pure air, but it probably has an important effect in assisting the formation of rain; it is made up partly of invisible organisms and partly of mechanically-derived fragments called dust. Apart from this consideration, we may say that the air consists of two gases, nitrogen and oxygen, mixed in the proportion of about 4 : 1, and water-vapour, generally at least 1 per cent. Other gases are present in very small quantities, but need not here be considered, except for carbon dioxide which, though usually making up only about 3 parts in 10,000, yet plays a very important part in the economy of life. It is essential to realize that these gases are quite free from one another, each showing its own characteristics and being able to act independently of the others; they are only mixed in the way that sand and sugar can be mixed and easily separated again. Nitrogen, although present in such large quantities, has the effect chiefly of toning down the oxygen; without it, in an atmosphere of oxygen, not only would our fires burn, but also our fireplaces and everything else, and we ourselves would have the whole activity and excitement of our lives packed into a few glorious hours. Oxygen supplies all living creatures, animals and plants, with the means of respiration; carbon dioxide, the product thus formed, is broken up by green plants again into carbon and oxygen, the latter being restored to the air.

*Physical properties.* The physical properties of air are those of gases and vapour acting independently. The most striking physical property of gases is that they expand and fill any vessel, no matter how small the quantity present. A gas, therefore,

exerts pressure on the whole internal surface of the vessel, the amount of pressure depending

1. on the amount of gas present ;
2. on its temperature.

In order to make the properties of gases appeal to children we may make use of the familiar example of the pneumatic tire of a bicycle. A little air exerts pressure, more air renders the tire harder by exerting more pressure on its walls. If we leave a well-inflated tire in the sunshine, the raising of the temperature of the imprisoned air has a well-known result. Further, the very slightest pin-prick in the tire will allow most of the air to escape. (Some remains in because it escapes only so long as the pressure is less outside than inside.)

Hence from the tire we unconsciously learn the five chief properties of gases :

1. to exert pressure in all directions ;
2. to expand when heated, unless it is confined in a rigid vessel, on the sides of which it will then exert an increasing pressure ;
3. to escape from a place where pressure is greater to one where it is less.

Also :

4. air becomes heated as it is compressed, for when we inflate a tire the rubber only expands to a slight extent and, when the expansion ceases, the pressure of the air inside the tire is rapidly increased by the pumping and the air becomes warmer. (The heating of the pump is partly due to compression of the air in it and partly to friction.)
5. if allowed to expand, air cools, for the escaping stream of air from the tire feels cold to the hand.

Besides the gases in the air we have water-vapour also to deal with, and this behaves in a different way ; its quantity is, however, extremely small. Under ordinary conditions, 1 cubic ft. of air at 0° C. will absorb only about 2·1 gr. of water-vapour.

,, 10° C. ,, ,, ,, 4·1 ,, ,, ,,
,, 20° C. ,, ,, ,, 7·5 ,, ,, ,,
,, 30° C. ,, ,, ,, 13·1 ,, ,, ,, &c.

If air at 0° C., containing 4 gr., is cooled suddenly to 9° C. it has to deposit 1·9 gr.; if to 4°, 2·1, and so on.

*Changes and movements of the atmosphere as constituting climate.* This brief consideration of the physical properties of gases and vapour is sufficient to show that the Earth's gaseous envelope must be in a condition of constant change. The changes and movements of the atmosphere and the effect of these on the passage of the Sun's rays through it constitute climate. Now two factors, i. e. climate and the nature of the Earth's surface, have control of the possibilities in every part of the Earth for plant-growth, and hence decide whether it can be occupied by animals and man. The scorched-up wastes of the Sahara are a direct product of climate, for the soil itself is by nature fertile. Climate, again, is responsible for the barrenness of Greenland's interior; during the few weeks of summer the whole coastal regions glow with life and colour, in striking contrast to the interior, which, being more elevated and consequently colder, never emerges from the snow and ice, except just its mountain-tops. Obviously then the condition of the atmosphere is one of the features we must study, in trying to understand the distribution of life on the globe.

In order to realize the fundamental principles determining climate, it will be necessary:

i. *to show that the atmosphere possesses weight or, in other words, exerts pressure;*

ii. *to show that changes of pressure occur and are due to certain factors;*

iii. *to consider how each of these factors, separately, influences climate: factor A, temperature; factor B, varying quantity of water-vapour;*

iv. *to study their combined effect, together with the Earth's movement of rotation.*

# VI. Pressure of the Atmosphere

## I. *The Atmosphere exerts Pressure in all Directions*

*The making of the barometer.* The fact that the atmosphere has weight was one of those great discoveries which, like so many others, was originally the result of accident. In 1643 three Florentine gardeners, trying to make a fountain, discovered that they could not pump the water higher than 33 feet. This astonishing fact was communicated to Galileo, and his pupil Torricelli hazarded the suggestion that possibly a column of water about 33 feet high exactly balanced a column of air the whole height of the atmosphere.

Starting with this supposition and knowing that mercury weighed $13\frac{1}{2}$ times as much as water, Torricelli proceeded to try whether a column of mercury about 30 inches high would behave in the same way. The simple apparatus he devised is still practically that of the ordinary barometer by which the pressure of the air is estimated. Torricelli took a glass tube rather over 30 inches long and closed at one end, filled it with mercury, and inverted it over a basin of mercury. The pressure of the air on the mercury in the basin sufficed to hold up the mercury in the tube to a height of about 30 inches. At the top a little vacuum formed, and Torricelli will be remembered for all time, because who else has had his name bestowed upon a vacuum ?

*Pressure of the atmosphere upon the Earth.* The pressure of the atmosphere upon the solid or liquid surface of the Earth is due really to the Earth's attraction ; if there were no Sun and the Earth were still, the air would be held to the Earth equally all over its surface, and so the pressure would be the same everywhere at sea-level. Here the layers of air, being compressible, would be denser than the upper layers resting upon them. This is, roughly speaking, the case, for the pressure at sea-level is greater than that at points above it ; in fact, at a distance of about 16,500 feet above, the atmospheric pressure is only about half that at sea-level. The pressure of the air in the lower layers never varies greatly, seldom as much as one-tenth ; yet this

little variation is sufficient to disturb the equilibrium of so elastic a substance.

We have proved then that the atmosphere possesses weight, as shown by the barometer. It is, however, more correct to say that it exerts pressure, seeing that the force is exercised in all directions.

We next pass on to show that :

II. *The Pressure varies within certain limits owing to Special Causes*

These causes are :

(*a*) The unequal heating of the Earth's surface by the Sun's rays;
(*b*) The influence of a varying amount of water-vapour.

The unequal heating of the Earth is due :

i. To the direction in which the rays fall : in other words, to the amount of atmosphere they have to penetrate before reaching the surface of land or water ;
ii. To the nature of the substance on which they fall ;
iii. To the intervention of mist and cloud, which form a screen between Sun and Earth.

*Unequal heating due* (i) *to direction in which rays fall.* If it were not for the presence of the atmosphere there would be little difference in the amount of heat received from the Sun on different parts of the Earth ; as it is, however, the rays which pass obliquely through the atmosphere have infinitely less heating power than the more direct rays. This can be seen at once by reference to a diagram (fig. 14). The Sun being so distant its rays are practically parallel.

Experience is, however, a more convincing guide. It is colder at sunrise or sunset than at noon ; it is warmer in summer than in winter, i. e. when the average height of the Sun in the sky is greater.

*Unequal heating due* (ii) *to nature of substance on which the rays fall.* The fact that land and sea absorb heat very unequally has an important bearing on pressure variations. A water-surface absorbs heat slowly, gradually and to a considerable depth,

retaining the heat thus absorbed for a long time. A land-surface takes up heat very much more quickly and only on, or very near, the surface, but loses it also far more quickly. Great differences in temperature are thus set up between continental and oceanic areas, and the unequal distribution of heat due to this cause has far-reaching consequences, as we shall discover later.

*Unequal heating due* (iii) *to intervention of mist and cloud.* Unequal heating is also due to the presence in the atmosphere of mist and cloud, which act as a screen from the Sun's rays. Directly a cloud passes between us and the Sun we feel that most

Fig. 14. The incidence of the Sun's rays as affecting insolation. The experiment shows that the amount of insolation depends on the incidence of the rays. The ray is passed through a circular aperture such as the stop of a camera. A ray falling vertically (as between the tropics) has much more power, as it passes through less atmosphere and is spread over much less surface than a ray falling obliquely (as north or south of the tropics).

of the heat from the rays has been cut off. Mist and cloud also prevent the heat reflected from the Earth's surface from passing out into space. So although cloudy days are cooler than sunny days because less direct heat is received, yet cloudy nights are warmer than clear nights because less heat can pass out and away.

(*b*) *Variation in amount of water-vapour present.* The second cause of change of pressure, i. e. variation in amount of water-vapour present, is really dependent partly on the first, i. e. temperature, and partly on whether there is any surface from

which water is being evaporated. As the greater part of the Earth's surface is water, and this is exposed to the atmosphere, vaporization is, as a rule, going on. When the temperature is high, much more water-vapour is required to saturate a given volume of air than is necessary when the temperature is lower. Thus, at a temperature of 32° F., only 2·11 gr. Troy per cubic ft. of saturated air are required, at 60° F. (the ordinary temperature of a room) 5·74 gr. Troy per cubic ft. are required, while at 115° F. as much as 29·89 gr. Troy per cubic ft. are required.[1] So, if the air is warm, vaporization of water is more rapid and greater in amount than if the air is cold.[2] Vaporization is also increased by any movement of the air, for if the vapour is removed as it is formed fresh layers of unsaturated air may be brought into contact with the water-surface. This is demonstrated by the rapid drying of clothes in a wind. When vaporization becomes continuous the process is known as evaporation.

*Dew point.* The temperature at which saturation-point is reached is called the Dew Point. If the temperature falls below this point, part of the water-vapour begins to return to the liquid state, i. e. to condense.

*Condensation and its results.* Hence anything which lowers the temperature of air saturated with water-vapour will cause condensation of the invisible water-vapour to visible water-liquid. If, from any cause, water-saturated air is made to expand, without heat being added to keep the temperature constant, the temperature will fall and cloud or rain will be formed. This condensation of water-vapour to water-liquid sets free some heat, for more heat is necessary to keep the water in the form of the more mobile vapour than is necessary to keep it in the less mobile liquid form. The heat thus liberated is called

[1] For table see Simmons and Richardson, *An Introduction to Practical Geography*, p. 303.

[2] In a crowded and heated railway carriage in winter, the warm air meeting the cold glass of the window is chilled and water pours down the window. It is said that once in Austria, the windows of a crowded and over-heated ball-room were suddenly all thrown open, so that the cold air could rush in. To the amazement of all present, snow immediately fell in the room.

latent heat. We frequently notice that rain, in falling, is accompanied by a rise in temperature, whereas the chilly feeling of a cold thaw is almost equally familiar, the change from the solid to the liquid form of the water being, in that case, accompanied by absorption of heat.

It is important for us to realize, while dealing with this subject, that the common statements, ' warm air is lighter than cold air ' and ' air containing water-vapour weighs less than dry air ', are not strictly true. Air expands on heating, so that a given volume contains less particles of it and is, consequently, lighter. If water-vapour is added to dry air, its weight is obviously increased by the weight of the water added ; but if more vapour is present, condensation is more likely to take place and the heat, liberated in this process, causes expansion and apparent loss of weight.

## VII. Temperature as a Factor in Climate

In order to realize the significance of the factors affecting climate, it will be best to consider each separately, taking first Temperature, as being on the whole the simplest. The Sun's rays, in passing through, do not seem to heat the air directly to any great extent, for away from the surface of the earth, although nearer the Sun, the air is cold. The presence of the atmosphere controls the temperature of the Earth's surface, however, in a remarkable degree. If there were no atmosphere, the scorching heat of the Sun's rays, received during the day, would be as quickly lost at night, and alternations of excessive heat and cold would, apart from any other consideration, render life, in its known form, impossible. As it is, the heat rays filter slowly through the atmosphere during the day and at night pass out again just as slowly. So the atmosphere acts like a kind of blanket enwrapping the Earth and tempers the heat of the day and the cold of the night. The presence of clouds causes the filtering process to be much slower still, hence frost is less likely to form on cloudy nights

than on clear nights, and in cloudless regions the nights are comparatively cold.

As mentioned above, the atmosphere is, in the main, not heated directly by the Sun, but, having allowed the Sun's rays to penetrate to the Earth, it receives and holds the heat radiated from the Earth's surface. This heat is retained in that part of the atmosphere which is densest and where water-vapour is present, i.e. within a distance of about two miles from the general surface or sea-level. As we climb a mountain and pass beyond this level, the temperature of the air sensibly diminishes and it is always cold at high levels. It is true that the Sun's rays on a calm clear day may feel very warm on the cheeks of a mountaineer and cause the skin to blister, but this is owing to the decreased density of the air on the mountain-top.

Until quite lately, it was supposed that the temperature of the atmosphere diminished regularly from the surface of land and sea to its outer limit, but recent investigations seem to show that, at heights greater than 7 to 9 miles, the temperature remains nearly constant at about $-70°$ F. As far as observations go, at any rate, further loss of temperature has not been found at greater heights, and for this reason the outer shell of atmosphere, where the temperature does not rise or fall, was called the isothermal layer. Although we know very little about this part of the atmosphere, it seems that the changes which affect the lower portions of the atmosphere as a whole, and the conditions of unrest which are common there, do not penetrate into this part, or only to a very slight extent.

Teisserenc de Bort, whose discovery of this distinctive upper layer, in 1899, led to a great deal of subsequent work, soon realized that the term isothermal layer was misleading, for the peculiarity of this part of the atmosphere is that there is no change of temperature with height. In other words, whereas nearer the Earth the temperature layers are horizontal and decrease from within outwards, in this portion of the atmosphere they are nearly vertical. This fact is made clear by fig. 42 in Lempfert's *Meteorology*, which shows the results of Ballon-Sonde ascents in 1907-8. For this reason, Teisserenc de Bort proposed the name

stratosphere[1] for this outer atmospheric shell and troposphere for the better-known portion enclosed within it.

The atmosphere may therefore be considered as consisting of two divisions, according to temperature:

1. An upper division, called the stratosphere, where the temperature remains the same apparently throughout.
2. A lower division, called the troposphere, which is distinguished by a fairly regular fall of temperature with height.

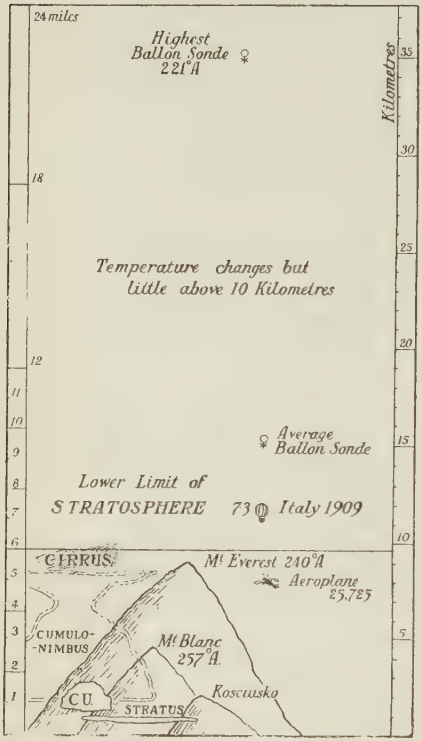



FIG. 15. Diagram showing approximate positions of stratosphere and troposphere. The troposphere extends upwards to the horizontal line. The present highest aeroplane record is 40,800 feet. CU. = Cumulus cloud. (From Griffith Taylor, based on Napier Shaw.)

The level where the change from one to the other takes place is sometimes called the tropopause.

The troposphere is thicker at the equator than at the poles, and the temperature of the superincumbent stratosphere is there coldest; indeed the coldest air in the atmosphere is to be found above the troposphere in equatorial regions.

[1] The word 'stratosphere' is rather an unfortunate one to choose in this connexion, as it has already been applied to the outer part of the Earth's crust, which consists mainly of stratified rocks; also it does not eliminate the suggestion of horizontality.

The level of the stratosphere is from about $6\frac{1}{2}$ to 8 miles above the sea-level and, except in the Arctic regions, is beyond the reach of aeronauts. Probably even in this part of the atmosphere some changes of temperature take place, and these affect the pressure near the Earth in a way that, at present, is not understood. By far the greater number of changes in the atmosphere, however, are confined to the troposphere.

*Vertical distribution of temperature in the troposphere.* The vertical distribution of temperature in the atmosphere can be approximately expressed as an average loss of 1° F. for every 300 ft. of elevation.

This can be represented graphically thus:

Supposing a place at sea-level has a mean temperature of 65°; if a horizontal scale represents temperature in degrees and a vertical scale altitude in feet, the lowering of the temperature according to elevation above this station can be expressed by the line A B, which for every rise of 300 ft. shows a decrease on the horizontal scale of 1° F. Horizontal lines drawn at intervals would give the daily temperature range at various altitudes, and would show that the range is shorter as the elevation increases, the greatest diurnal range of temperature being nearest the Earth.

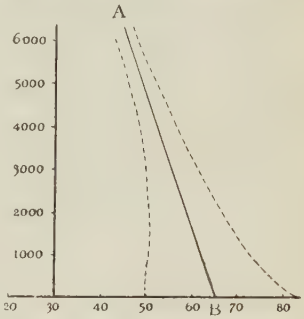



FIG. 16. Diagram showing decrease of temperature with altitude. (Partly after W. M. Davis.)

*Horizontal range of temperature. Insolation climate.* Having now seen that the atmosphere has a kind of stratification according to temperature, it is clear that, for purposes of physical geography, we can confine our attention to the lower layer, or troposphere, the region where the temperature decreases away from the surface of land and water. We have seen that within the troposphere itself there is a definite horizontal as well as a vertical temperature change, this being due to the fact that rays passing to the bottom of the atmosphere at right angles

to the surface of the Earth are more intense than the rays that come slanting through and spread themselves over a wider area.

The diagram (fig. 17), showing the effect of the Sun's rays in different parts of the Earth at sea-level, proves conclusively that the power and intensity of those rays are far greater at the equator than at the poles, when the Sun is overhead at the equator at noon. If therefore the surface of the globe were all land or all water and the Sun were always overhead at the equator at noon, the temperature would be highest at the equator and gradually become less and less until the minimum was reached at the poles.

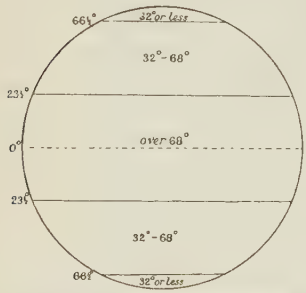



Fig. 17. The Insolation or Mathematical Climate of the Earth, the average temperature of each part being based on the amount of Sun's heat received.

The inclination of the Earth's axis helps to supply useful boundary-lines to a series of temperature zones which can be marked out on the Earth's surface. Thus, the inclination being about $23\frac{1}{2}°$ from the perpendicular, the Sun is overhead some time in the year at every place within $23\frac{1}{2}°$ N. and $23\frac{1}{2}°$ S. of the equator. This region is called the Torrid Zone and the boundary-lines are the tropics. Again, the inclination causes the Sun's rays to shine continuously for six months on every place within a distance of $23\frac{1}{2}°$ of the poles, but to be entirely cut off for another six months in the year. These two regions, round the north and south poles respectively, are called the Frigid Zones and their boundaries the Arctic and Antarctic Circles. The regions between these two sets of lines, the Arctic Circle and Tropic of Cancer on the one hand and the Antarctic Circle and Tropic of Capricorn on the other, are called the North and South Temperate Zones (see fig. 13). These astronomical zones were known to the ancients. The word 'climate' (Greek *klimata*) means 'inclinations' and was first introduced by Ptolemy, who divided up the zones according to the length of the longest day

in different parts of the Earth. The average temperature of the zones can be shown; see p. 62, fig. 17.

This gives us what is called the insolation or mathematical climate, i.e. the climate which should result from the actual amount of Sun's heat received in each part of the Earth. In reality, however, the climate varies so much within the zones, owing to other causes, that these divisions are of little value except for reference.

The rotation and revolution of the Earth as causing the alternations of day and night and the length of the year, the way in which alternations in the length of day and night in different zones produce the seasons, and how far the longer day counterbalances the lower Sun, are subjects which have been admirably dealt with in the text-books and so are not included here.[1]

*Insolation climate contrasted with actual climate.* The reason why the insolation climate gives so little clue to the actual climate, in any part of the Earth, is easily seen when we study the effect of difference in the material constituting the surface upon the heat received. If the surface were all alike, i. e. all land or all water, the symmetrical arrangement would for the most part obtain, and indeed almost does so, south of the great land-masses. North of this region, however, as land heats more rapidly than water and also loses its heat far more quickly, the simplicity of the arrangement is disturbed by the existence of adjacent areas unequally heated.

*Illustration by means of Class-room Experiment.* The presence of such areas and the general effect of this on the atmosphere can be better understood if the subject is first studied on a small scale in a room, and the following experiment is of very great assistance in enabling a class to realize these differences and their results.

Take about a dozen thermometers (those marked with Fahrenheit degrees on one side and Centigrade on the other are most useful) and

[1] See T. H. Huxley and R. A. Gregory, *Physiography* (London: Macmillan & Co., 1904), chapter xix; R. D. Salisbury, H. H. Barrow, and W. S. Tower, *Elements of Geography* (New York: Henry Holt & Co.), chapter v.

place them on chairs all about the room, some in the centre, one near the door, others near windows, and others near the fireplace or heating apparatus.

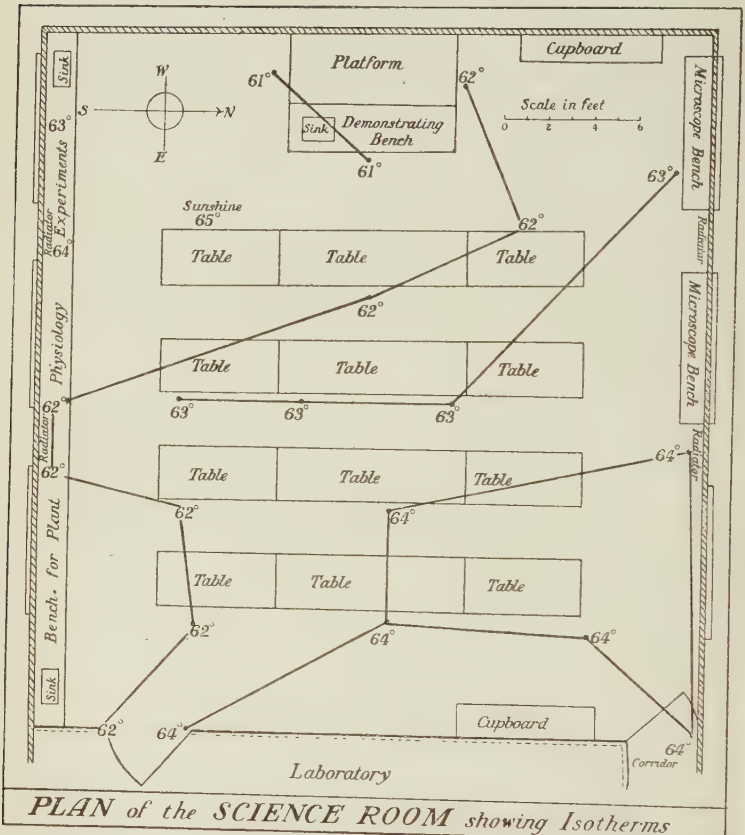



FIG. 18. Plan of Science Room, The Queen's High School, Chester, to show existence of adjacent areas unequally heated. (Drawn by Joyce Ayrton, Form IV Upper.)

Make a plan of the room (on squared paper) showing the positions of the thermometers.

Take a reading of each thermometer and mark it on the plan.

By drawing lines between the thermometers on the plan, connect those which read alike.

These connecting lines represent lines of equal temperature and are therefore called isothermal lines or isotherms.

In this way a complete chart of the thermal conditions in the room is obtained, and we also get a clear grasp of the meaning of temperature charts in general.

A smouldering match carried about the room will usually show that the air under such conditions is not still, but currents are passing in definite directions.

The direction and meaning of these currents can be explained as follows :

In a room with doors and windows, heated by radiators, the air in actual contact with these radiators is at a higher temperature than the rest of the air in the room, whereas near the doors and windows the temperature is lower. The superheated air expands owing to the heating, its specific gravity is thus reduced and it floats on the top of the cooler and heavier air around it, as oil floats on water. When it reaches the ceiling it can no longer move vertically and is therefore forced along horizontally, thus reaching colder parts of the room. Soon its temperature is no higher than that of the air near it, and so, as the colder air moves towards the radiator to take the place of the hot air that has passed away from it, each particle, in the end, makes a complete circuit, returning to the radiator again. As the average temperature of the room rises, the contrasts in temperature between different parts of the room are lessened and the circulatory movement becomes less active.

*The process of convection.* The process by which a fluid when warmed flows from a place of higher to a place of lower temperature is called convection,[1] and affects very readily such easily-moved media as water and air ; in the open air, in fact, convection currents are mainly responsible for wind. A right understanding of these, the general results of convection, is of first importance in studying such fluids, and an explanation of the thermal conditions obtaining on the surface of the globe is less difficult if we keep in mind the facts learnt from the above experiment.

*The actual distribution of temperature.* As stated at the

[1] The most striking example of convection that the writer has ever seen was observed one summer's day from the top of the *Gornergrat*. The sky was cloudless and there was no wind : the heat of the Sun's rays was intense. Some barbarian had tried to throw away a large piece of lunch-paper, instead of burying it. The paper, caught by the convection currents, was carried vertically upwards. Being crumpled, it wobbled as it went, but never changed its course. It went up and up, until at last the tiny speck seemed to melt into the blue.

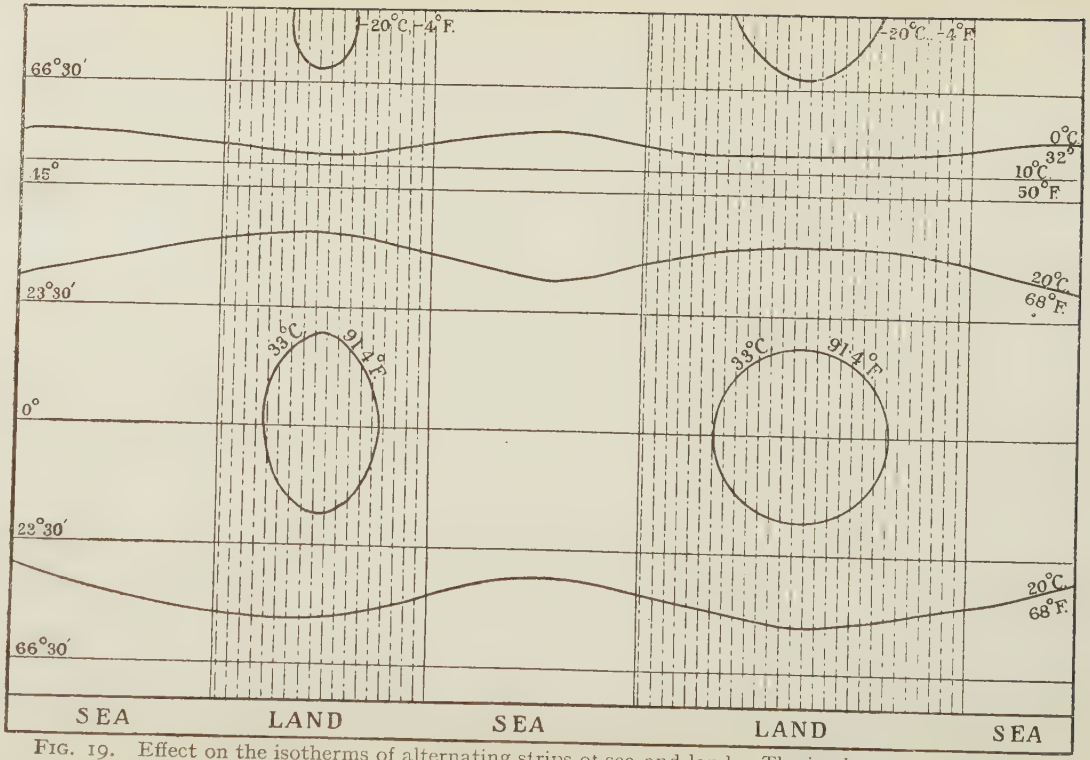



FIG. 19. Effect on the isotherms of alternating strips ot sea and land. The isotherms tend to bend round the land. (After Supan.)

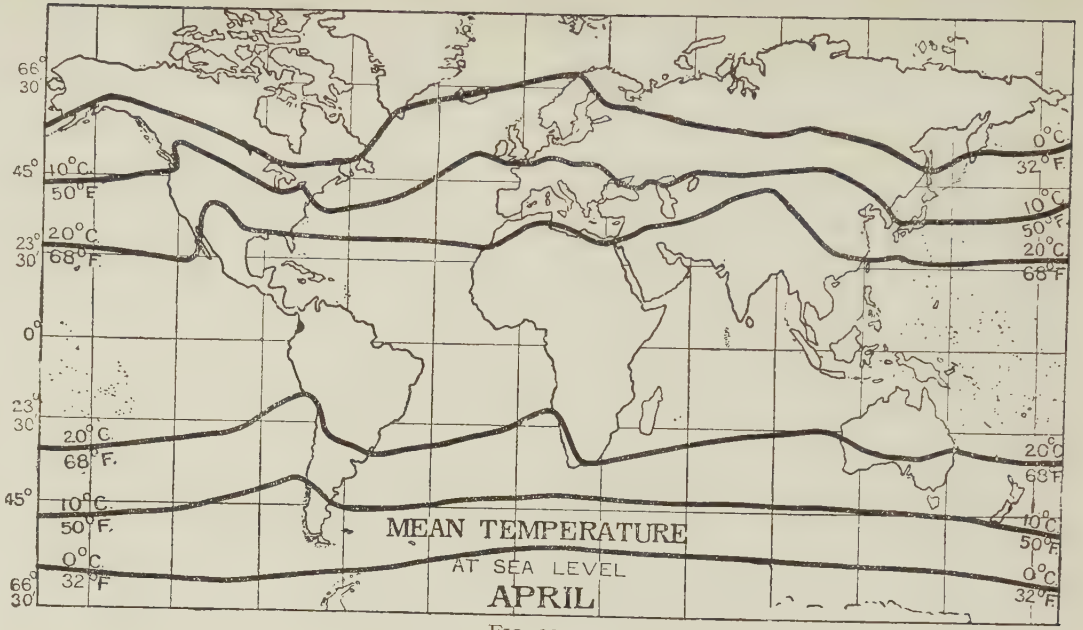

66° 30'
45°
23° 30'
0°
23° 30'
45°
66° 30'
10°C. 50°F.
20°C. 68°F.
20°C. 68°F.
10°C. 50°F.
0°C. 32°F.
0°C. 32°F.
10°C. 50°F.
20°C. 68°F.
20°C. 68°F.
10°C. 50°F.
0°C. 32°F.
MEAN TEMPERATURE
AT SEA LEVEL
APRIL

FIG. 20.

beginning of this chapter, if the surface of the globe consisted of homogeneous material, we should not have to contend with the difficulty of unequally heated areas, and the isothermal lines, or lines of equal temperature, would run parallel to one another and parallel to the lines of latitude. The fact that the land takes up heat more quickly and parts with it more quickly than the water is familiar to us—especially on a hot summer's day, when the cool sea ripples over the scorching sand—and the whole Earth's surface consists of alternating masses of land and water. To get a clear idea of the effect of this on temperature, we must wipe out all preconceived notions of irregularly arranged masses and reduce the surface to its simplest terms. We shall then see that between lat. 80° N. and 50° S. the surface virtually consists of alternating strips of land and sea, running north and south, i.e. at right angles to the direction of the ideal isotherms. Thus the parallelism of the belts of equal temperature is disturbed. In the hottest and coldest parts of the Earth where land occurs, the isotherms close in round the land-areas. This is due to the highly heated land-areas near the equator and exceedingly chilled land-areas near the North Pole. In regions where the temperature range is not extreme, the difference between sea and land heat is far less, and there the isotherms show little disturbance. The accompanying diagram (fig. 19) illustrates this extremely well.

On comparing this with a chart (fig. 20) showing the mean annual isothermal lines we see that a great similarity obtains.[1]

It will be noticed, however, on the chart that the actual hottest and coldest regions are not quite central in the land and sea areas. This is due to the winds, and its cause will be further explained under ' Winds '. It suffices here to show that the result is as in Professor Supan's plan, except that the effects of land and sea are shifted to the eastward, so that the sea-climate extends partly across the western part of North America and Asia, and the land-climate extends partly over the Western Atlantic and Pacific.

[1] The factor of altitude has to be left out of account in making these maps. For its influence see below, p. 69.

To summarize, we see :

1. That where there is no land-influence the isotherms are nearly parallel with the equator.

2. That the places with the hottest mean annual temperature are the equatorial land-masses ; the hottest region in each case being a little to the east of the centre of the land so as to extend also partly over the ocean.[1]

3. That, near the equator, the hot region extends furthest north and furthest south where there is land.

4. That in higher latitudes the curves in the isotherms show the contrary effect, i.e. that the land is definitely colder than the sea.

5. The coldest regions are North America and Asia, but are not quite in the centre of the land, being shifted distinctly to the east.

An isothermal chart is very helpful as giving an excellent idea of general temperature distribution, and, for ordinary purposes, it is not necessary to go beyond this. If we want to be absolutely correct, however, we must realize that the isotherms are drawn from temperature-readings corrected to sea-level and take no account of height. The effect of altitude complicates matters, for the temperature falls as we mount above sea-level at the rate of about 1° F. to 330 ft.[2] or 20° to a mile. By means of free balloons it has been found that, at about six miles altitude, the temperature is about 70° below freezing-point (Fahrenheit scale) ; so, on a mountain-top within the tropics, we may be above the snow-line and yet an isotherm map will show the region as very hot. In the study of geography it is important to know the actual and not the sea-level temperature, but the maps showing this are a little more complicated than those showing temperatures corrected to sea-level.[3]

[1] The maps do not show this except in the case of South America, but it is clear that the warmer parts of the oceans are not central, but towards the east.

[2] Corrections to sea-level are made thus : if the temperature of a place at an altitude of 3,300 ft. is 60° it will be entered on the chart as 70° (60° + 10°).

[3] For a clear and more detailed account of ' Horizontal distribution of Temperature ' see P. Lake, *Physical Geography* (Cambridge University Press, 1915), chapter v.

## VIII. The Distribution of Water in the Atmosphere

Turning now to consider the influence of water in the air, we find it has a double, or even treble, part to play :

*Invisible water-vapour.* In the first place it exists as an invisible vapour. On a very cold dry day the air will contain hardly any water-vapour, on a very hot day under certain conditions as much as $2\frac{1}{2}$ per cent. of the air may be water-vapour. The presence of a greater or less proportion of water-vapour has a very marked effect in producing differences of pressure and will be considered fully in the next chapter.

*Condensation of vapour.* In the second place the air may be so charged with water-vapour that some is obliged to condense because, as we saw above, not more than a certain amount can remain as vapour at a given temperature. The water-vapour, on condensing, may take any of the following forms :

1. Mist, fog, and cloud,
2. Dew and hoar-frost,
3. Rain and snow.

When the water-particles become visible in the air, but remain suspended in it, they form either mist, fog, or cloud.

*Mist.* Mist consists mainly of pure water-particles, condensed in the air owing to chill of contact. On mountains, mists are frequent, either because warm air meets a cold surface or because the warm air, rising from the plains or valleys, passes into colder layers of air.[1]

*Fog.* Fog, on the other hand, arises when the water, in condensing, clings to dust or smoke particles which, in fact, help it to condense; hence a London fog. A Channel fog is not a misnomer according to this definition, for, although the air over the sea is practically free from dust and smoke, the solid nucleus

[1] The present writer was once chased up the Gemmi Pass by the valley mists, which, passing the traveller half-way, greet him again at the top, where they reappear like tiny curled feathers resting on each mountain peak.

seems to consist of minute salt particles derived from the sea-spray. Another distinction between mist and fog is that the former envelops the traveller like a blanket, soaking wet, whereas a fog is dry and, when it is dense, the smoke particles may produce a parched feeling in eyes and throat.

*Cloud.* Cloud is of the same nature as mist, but is formed high up in the atmosphere.

The different kinds of cloud have been well dealt with in various text-books, and are so beautifully described and illustrated by Mr. Clayden in his book *Cloud Studies* that we need not go into details here.[1]

All of these, i. e. mist, fog, and cloud, screen off the Sun's rays from the Earth in the area where they occur and therefore tend to reduce the temperature of that part.

*Dew and frost.* Sometimes small drops of water form upon the land, because the chilling of the land's surface lowers the temperature of the air near it below dew-point. This is called 'dew', or, if the temperature is lowered below freezing-point and ice-particles form, it is called 'hoar frost'. It will be observed that dew does not *fall*, but *forms* where it appears—or may even rise from the ground.[2] Only a poet's licence will permit of the expression :

'The dew was falling fast.'[3]

*Rain.* The part played by water is not limited to the cases mentioned, since, by condensation, not only mist and cloud are formed, but actual precipitation takes place and rain is produced. In considering climate the importance of rain cannot be overstated. Countries which can be sure of a sufficient rainfall need nothing more than a passably good soil to ensure a measure of fertility; whereas, without rain, the most fertile land may be desert except when irrigated, and irrigation is extremely costly and only affects a relatively small area.

[1] The present writer was once, in Scotland, watching on a hot day the gradual disappearance of a cumulus cloud. Suddenly she saw it beginning to reappear as a cirrus, much higher up.

[2] For experiments on dew see Lake's *Physical Geography*, p. 89.

[3] See Wordsworth, W., 'Poem of Barbara Lewthwaite'.

*Conditions necessary to form rain.* The conditions necessary for the formation of rain are :

1. Sufficiently great evaporation.
2. The transference of the vapour-laden air from the place where it forms to another ; e. g. by wind, which moves the saturated air from over the ocean to over the land.
3. The lowering of the air's temperature so that it can no longer retain all its moisture.

*Convection.* The main cause of rain is the rising and consequent expansion of air. The air on expanding cools, as was seen in the case of the air flowing from the bicycle tire. The cooling leads to condensation which, taking place in this way, produces clouds. In the cooling air each water-particle of the cloud is a surface on which more water may condense till the water-drops are too large and heavy to remain in the air, so they fall to the ground as rain. The formation of rain is greatly assisted by the presence of dust-particles, which also serve as centres of condensation.

Conditions favourable to the formation of rain by rising air are found near the equator, within the tropics and in the monsoon region. The names of these areas can conveniently be used to designate the kind of rain produced.

1. *Equatorial rain.* Equatorial rain is formed near the equator in the region known as the equatorial rain-belt or doldrums. Here there is a constant uprising current of warm, moisture-laden air. As the air rises it can expand still more, the quantity covering a square foot at sea-level having to cover a larger area at a distance above it. The consequent cooling produces a very heavy rainfall, for the temperature of the air is high and the quantity of water-vapour great. The rain-belt migrates to some extent with the Sun, but is greatly influenced by the distribution of land and sea, so that it penetrates, on the whole, further north than south. It regulates the rainy season or seasons within the tropics.

2. *Tropical rain.* Tropical rain falls near the northern

tropics during the northern summer and near the southern tropics during the southern summer. As the Sun, vertically overhead, follows its apparent path from the tropic of Cancer to Capricorn and back again, those regions are invaded by tropical cyclones. These are due to two causes, one of which is convection, for the rain seems to be produced by a current of warm air rising. The other characteristic of the cyclone—its onward and rotary movement—is ascribed to the poleward deflection of the wind caused by the Earth's rotation and will be dealt with under ' Pressure '. Owing to the unequal distribution of land and sea north and south of the tropics, tropical cyclones do not enter the South Atlantic.

3. *Monsoon rain.* Warm air rises by convection over heated land-areas in summer and less warm currents flow in from the sea to take its place. This moisture-laden air, when drawn upwards, expands, becomes cooler and produces thus the summer rains of the monsoon regions.

Convectional rains, as hitherto described, are therefore of three distinct kinds, and, as only one of these kinds is wholly convectional, it is proposed to classify them as above.

4. *Orographic or mountain rain* (*not convectional*). In mountain regions warm air rises, *not* owing to convection, where a mountain barrier lies across the path of the wind. The air on the windward side of the mountain chain is then forced upwards, expands and cools, and the water-vapour in it is condensed to rain, which falls on the windward side of the mountains. The behaviour of the wind when it reaches the other side of the barrier is best dealt with here also. When the air-current has crossed the summit of the ridge, it creeps down the other side to lower levels, i. e. to regions of greater pressure and warmth ; it consequently becomes warmed by compression and, having parted with most of its moisture on the windward side, it now takes up all the particles of water it can and becomes a drying wind. Hence the leeward side of a mountain range has little rain, and this relatively dry area is sometimes called the ' rain shadow '. A good example of this is seen in the Western

Cordilleran region of North America. The western or windward side is clothed with a very luxuriant vegetation, while the rain shadow side is dry prairie or grainlands.

*Class illustration of orographic rain.* A good practical way of showing the effect of the ridges is to cut out in paper the shape of the region of greatest rainfall in the Cordilleran region from a rainfall map, making the scale agree with that of a large wall-map. It is found that the rainfall areas fit on to the windward side of the ranges, and the rain shadow area is easily made out also.

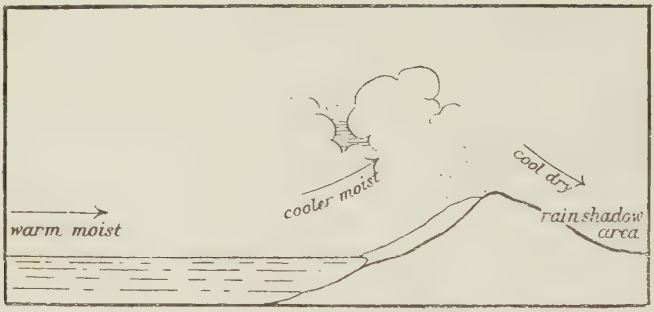



Fig. 21. Orographic or Mountain Rain.

The rain produced in this way has been termed ' Relief Rain ', but the word is rather ambiguous, and ' Orographical Rain ' or, more simply, ' Mountain Rain ' seems better.

5. *Cyclonic rain of temperate regions.* The cyclonic rains of temperate regions occur towards the centre of extra-tropical cyclones, which are similar in action to those of tropical regions, but are probably of quite different origin. There is, for instance, no proof that convection goes on to any extent in such cyclones; moreover, the air in the centre is colder and they occur mainly in winter.[1] Rain in the central part of these cyclones or whirls seems to be formed by uprising converging currents of air subjected to a whirling motion. In the absence of this whirling motion—

[1] *Local* convectional storms take place in the temperate zone in summer owing to the indraught of cooler air from outside. Thunder-storms are of this nature.

due, it is thought, to the Earth's rotation deflecting all currents to the right in the northern hemisphere—similar converging currents of air seem able to produce cloud or mist, but not rain. The structure of these cyclones will be further described below.

6. *Coastal or border rain.* A current of moist warm air from the ocean, advancing over a cold winter land, is also effective in producing rain. This may be called Coastal or Border rain. It is difficult to get a good example of this, as in most areas other influences—such as frequent cyclones or mountain ranges—affect the rainfall. But the rainfall of Australia is a fairly good illustration, though in the south-east the mountains near the coast are the most important factor.

Having now traced the causes of rain, in so far as they can be made out at present, we next turn to its distribution. No complete rainfall maps exist showing the distribution of rain over both land and sea. Except in the North Atlantic, few observations have been taken over the sea, and they are extremely difficult to make with any approach to accuracy.

If we study a rainfall map we see that although the distribution appears irregular, it is possible to make certain rough generalizations.

These are :

1. Rainfall decreases from the equator to the poles.

2. It diminishes from the coasts of a continent towards its interior.

3. Within and a little beyond the tropics (from about 40° N. to 35° S.) the winds bring rain to the *east* coasts.

4. In middle latitudes (45° to 65°), the westerly winds cause rain to fall first on the *west* coasts.

5. Mountain ridges running parallel with a coast, or bold coastal outlines facing the ocean, have a well-marked rainy side to windward and a rain shadow to leeward.

6. Within the tropics, convection and coastal relief are the chief causes of rain, cyclones being quite subsidiary.

Outside the tropics, cyclones are the chief rain-makers. Relief has some part to play, but, except for occasional summer storms in continental areas, convection is unimportant.

Making a closer study of the map, we now find :

i. Equatorial or sub-equatorial rains accompany the low-pressure belt in its migrations, passing with it further north than south, because there is more land to the north. Thus we get very heavy rain just north of the equator in the northern summer.

The lands affected are :

In the northern summer :

The Orinoco Basin and north side of Amazon basin, Central America ;

The Sudan and head-waters of the Nile ;

The peninsula of India, further India, the East Indies.

In the southern summer :

Southern part of Amazon basin, Brazil highlands ;

Basins of Congo and Zambezi, Madagascar ;

Southern East Indies and extreme north of Australia.

The windward side of the mountains within the tropics being the east side, there are rain shadow areas west of South America and west of Africa, south of the equator.

ii. The monsoon rains reinforce the above rains in summer, particularly round about the Indian Ocean. The indraught towards the land from this ocean in summer causes the excessive rainfall of northern India, especially Bengal, and its influence is felt all along the coast through China to Japan.

iii. Tropical cyclones also bring rain to the Indian Ocean, especially the southern part and the northern gulfs. They affect also the Philippine Islands and Japan and constitute the typhoons of the Chinese coast. Their other chief sphere of influence is the Gulf of Mexico, where they form the hurricanes of the Windward Isles, and—there being no high land-barriers in the Eastern States—the rainy effect of these penetrates beyond the tropic into the lower Mississippi basin.

iv. Orographic or mountain rains, although they may occur wherever the necessary conditions are found, are most marked in the region of temperate cyclones and will be considered with them. In these regions, i. e. the temperate zones, the rain develops mainly along east-west lines and comes mostly from

the west, so that west coasts, if high, receive a copious rainfall.

v. Temperate cyclones bring rain right across northern and central Europe and Asia with a very marked decrease from west to east; and also to the east coasts. In the eastern United States also a sufficient rainfall from this cause is found further inland because of the far-westward extension of the Gulf of Mexico.

All the west coasts, i. e. the Pacific coast of North America, west of Greenland, Iceland, Norway, and north-west British Isles, receive a plentiful supply of rain.

In the South Temperate Belt, the south of South America is again well watered on the windward side, i. e. the west side of the Andes; so also are the islands of Tasmania and New Zealand.

vi. The lands which make up the Mediterranean coast, also South Australia and South Africa, are somewhat exceptional as regards their rainfall. In summer they become almost tropical, especially where, as in the Mediterranean, they have a strong northern barrier. In winter, the equatorial rain-belt having migrated south or north, these areas come under the sway of the westerly winds and are consequently invaded by temperate cyclones, which are the rain-producing factors where these winds prevail.

The rainfall map shows also regions of excessive drought. These are either:

(*a*) The leeward side of mountain ranges or areas surrounded by a ring-fence of mountains;

(*b*) The centres of continents;

(*c*) Regions where winds blow from a cooler to a warmer part and therefore tend to absorb moisture in passing, as in the sub-tropical high-pressure belts; or regions to which winds blow from a land-area, e. g. N.W. Australia;

(*d*) Regions of intense cold, where the air naturally contains little moisture.

These causes may also act in combination.

(*a*) The leeward side of mountain ranges is the west side within the hot belt (fig. 38) and the east side north and south of it.

Rain shadow deserts outside the tropics are: the region east of the North American coast ranges, between these ranges

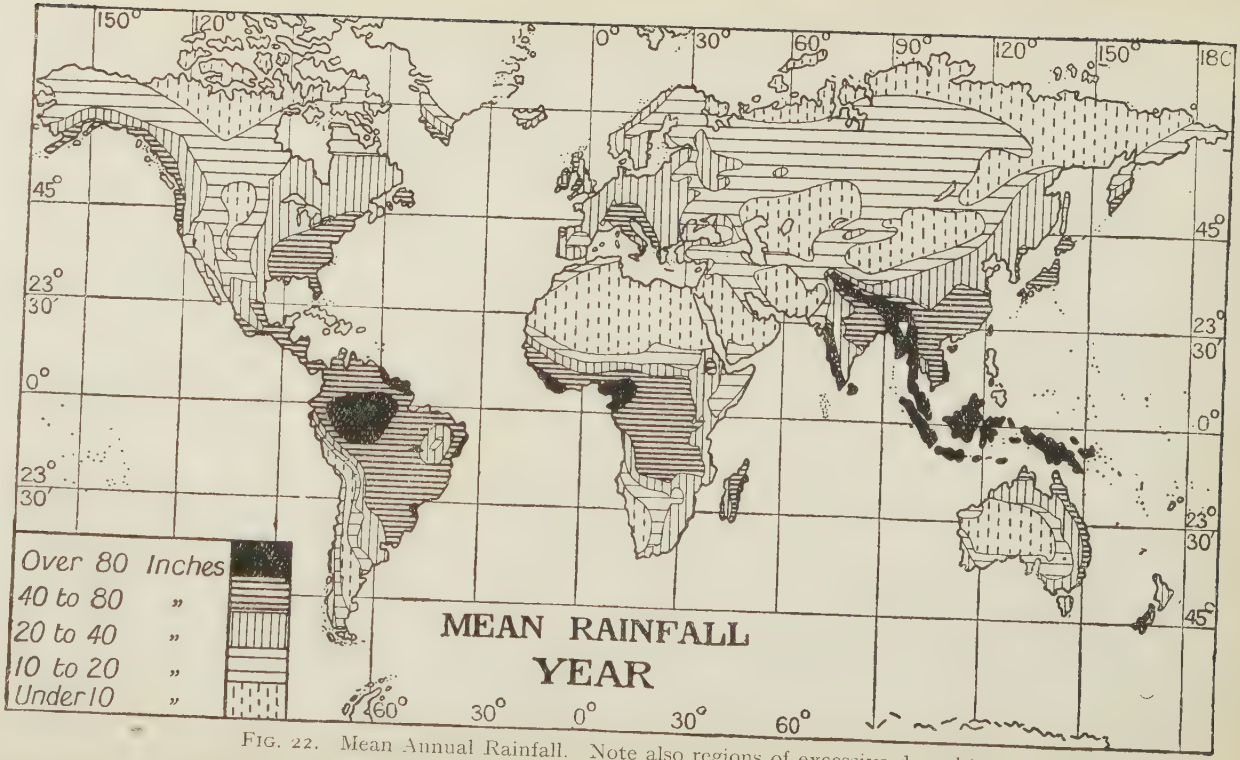



FIG. 22. Mean Annual Rainfall. Note also regions of excessive drought.

and the Rocky Mountains, known as the Great Basin region. The Rockies being higher than the coast range, rain falls again on them, but their rain shadow is very extensive, its influence spreading practically across the continent eastward. This region is not actual desert, but serves as grass and grain lands.

A smaller rain shadow desert occurs on the east side of the Andes in Patagonia. Tibet is on the leeward side of the Himalayas, which are watered by the south-west monsoon. Within the tropics, the west of northern Australia, the west of the Andes, and the west of southern Africa, already mentioned as affected by the trade winds, are also on the leeward side of the mountains and therefore dry for two reasons.

(*b*) Deserts in the centre of continental land are :

The desert of Gobi in Asia ; this is also on the rain shadow side of mountain ranges and partly surrounded by a ring-fence of mountains ;

Central Asia, round about the Caspian and Aral seas ;

Central Australia, also a rain shadow region and partly surrounded by high coasts.

The central part of North America has been mentioned above as dry but not desert, partly owing to the beneficent influence of the Gulf of Mexico, aided by the absence of barriers.

(*c*) The great deserts are due mainly to wind blowing from a cooler to a warmer region. Such are the deserts of Sahara, Arabia, and Persia in the northern hemisphere ; Atacama, Kalahari, and Central Australia in the southern.

(*d*) The Arctic and Antarctic desert regions are due to extreme cold, and also the atmosphere contains little moisture. When snow falls it renders the land fertile only on its melting, but over a great part of this area the heat is never sufficient for this, as is seen in central Greenland and the Antarctic continent. The whole of northern Asia, north-east Europe, the north of North America, and any other land in these latitudes is consequently either wholly or partially barren. For the same reason we have barren tracts wherever the land is too elevated, and therefore too cold, for the snow to melt, i. e. central Switzerland, the Himalayas, Andes, Rockies, &c.

*Summary.* There are regions of very great rainfall in the land-areas on both sides of the equator, sometimes extending to and a little beyond the tropics, i. e. South America, Central Africa, part of India, further India, the East Indies, and the north of Australia. We notice that, in these tropical regions, the rainfall reaches its maximum where bold eastern coasts face the ocean.

Outside the tropics the regions of greatest rainfall are where the sea-climate, which was shown to exist on the isothermal map, partly extends over the land and consequently the warmer air is chilled. Here the temperate cyclones are most felt. This occurs on the eastern margins and to a much smaller extent on the western margin of the Pacific and Atlantic Oceans, and is further assisted on the Pacific coast of North America and in north-west Europe by coastal elevation. The other main area of great precipitation is the north side of the Mediterranean Sea extending to the Black Sea, and is caused by the warm winds being intercepted by lofty mountain chains.[1]

Areas of insufficient rain are found in certain parts of the trade-wind region, where the land has a broad extent east and west so that any moisture brought by the wind is exhausted; also where, as mentioned above, the trade-wind is a drying wind. North of the equator this can be traced on the leeward sides, i. e. the west of North America, North Africa, Arabia, north-west India, and south of the equator on the west of South America, Africa, and Australia.

Regions of special dryness have been accounted for above. Between these extremes we get, generally, a sufficient rainfall, decreasing gradually from the rainy to the rainless regions. Thus, broadly speaking, rainfall is determined by :

1. Temperature;
2. Direction of wind;
3. Relative positions of sea and land;
4. Elevation.

[1] By cutting out the shapes of the areas of sufficient rainfall and superposing them on a map of the same scale, useful deductions can be made : (1) as regards vegetation areas ; (2) as regards population. Other determining causes, such as geological structure, have also to be considered.

# IX. Distribution of Pressure and Circulation of the Atmosphere

*The Effects of these various Climatic Elements combined with the Influence of the Earth's Rotation*

HAVING now realized that changes in temperature and in the amount of water-vapour influence the pressure of the atmosphere, and having considered the way in which each of these factors works by itself, we next proceed to study their combined effects on the atmosphere of the Earth.

The actual phenomenon observed is that the lower part of the atmosphere is never still, but has a circulatory movement, due to the formation of air-currents passing from regions of high pressure to those of low. Considering the Earth's surface as homogeneous and thus disregarding minor disturbances, we notice there are certain persistent areas of high and low pressure, which alternate as in the diagram (fig. 23), and that the direction of the winds is, in every case, away from a region of high pressure and towards one of low. We have now to explain :

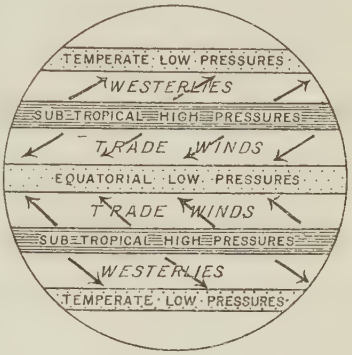



FIG. 23. Positions of chief High- and Low-Pressure Belts and Directions of Resulting Winds. We have also evidence to prove the existence of a high-pressure area over each pole, but these are not shown in the diagram.

1. The presence of these belts ;
2. The deflection of the winds from due north and south.

The presence of the low-pressure belt over the equator, as shown in the diagram (fig. 23), and the areas of high pressure at the poles follow naturally on convection. Thus, if the axis of the Earth is at right angles to the Sun's rays, the air at the equator, being relatively more heated than elsewhere, expands upwards and, its pressure at the surface being thus reduced, it is easily

shouldered up into higher layers by currents creeping in beneath from regions north and south of it. The air thus pushed up forms a higher column at the equator, and, the pressure on these forced-up higher layers being greater than that on surrounding layers, an outward flow of air to north and south is set up in these higher layers. This flowing off above causes decrease of pressure at sea-level in the region of the hot belt and increase of pressure north and south of it [1] (fig. 24).

The ideal circulation of the lower atmosphere, on a planet with its axis vertical to the Sun's rays and a homogeneous surface,

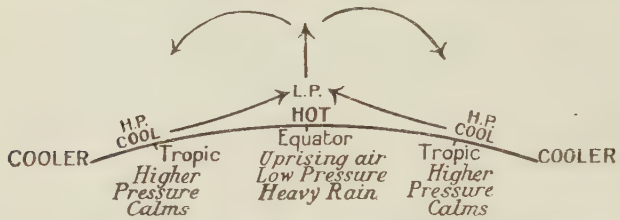



Fig. 24. Showing circulation of Air-currents in the Troposphere within the Tropics. Pressure at L.P. is less than at H.P.; winds blow from H.P. to L.P. Pressure above L.P. is still low, but higher than above H.P., so winds blow from the former to the latter. This would show roughly the circulation on a non-moving Earth.

would therefore be a high-level outflow from the equator towards the poles, compensated by an inflow towards the equator, there being low pressure over the equator and high pressure over the poles. The high-level outflow will not necessarily all reach the poles; some will form short circuits, bending round and flowing towards the equator again, and some, becoming cooled in higher strata and also compressed by the distance between any two meridians being lessened as the pole is approached, will tend to descend and flow as a surface wind intermediately between equator and poles.

So far we have failed to account for:

1. The deflection of the winds from due north and south;

[1] The chief difficulty about all this is that the temperature varies so little. In the Pacific, the mean air temperature varies only about 3° over 40° of latitude, of which the equator is mostly the middle line.

2. The existence of high-pressure belts intermediate between equator and poles;

3. The prevailing westerly winds of temperate regions.

*Deflection of the winds.* If the Earth were stationary and the sun were revolving round it, the above conditions should obtain; but, as the Earth is not stationary, but rotates from west to east, the direction of the winds blowing from regions of high pressure to those of low is affected. The law governing this deflection, enunciated by Ferrel, is generally explained by saying that the wind blowing from the region of less velocity to that of greater,[1] i. e. towards the equator, lags behind and consequently has its course deflected to the west. On the other hand, a wind travelling polewards has a greater velocity than the part of the Earth to which it is moving and so blows from the south-west in the northern hemisphere and from the north-west in the southern.[2]

*Tropical high-pressure belts.* The existence of high-pressure belts, intermediate between equator and poles, has not as yet been satisfactorily accounted for. They may have been produced partly by the deflection of the winds. This deflection being to the right in the northern hemisphere, the region of greatest pressure is not at the pole, but at some distance from it. Again, as the upper currents flow polewards, they must become crowded together, and this must cause compression. Davis explains the high-pressure belts as being the edges of polar whirls. Centrifugal force being engendered at the poles owing to the Earth's rotation, the region of high pressure, he says, is shifted from the

[1] 1. To show that a globe rotates much more rapidly at the equator than towards the poles, open an umbrella and pin a piece of paper with a word printed on it near the margin of the umbrella and another on the surface near the stick. If the umbrella is twirled quickly round, one word can be read and the other cannot.

2. To illustrate deflection of the wind, open an umbrella, holding it handle downwards, and spin it slowly round from left to right; an arrow held against it, pointing away from the end of the stick, represents a north wind. The arrow is travelling with the umbrella along a path to the right, but its point is further away from the stick than the rest of it is, and therefore is in a part that is travelling more quickly. So the wind that would have been a north wind, i. e. parallel to the rib, in travelling round ceases to be parallel to it because its point lags behind; consequently it appears to be a north-east wind.

poles to the neighbourhood of the tropics. The difficulty here is that this theory seems to require definite low-pressure areas at the poles, whereas they remain high-pressure areas.

*The westerlies.* Owing to the presence of these high-pressure belts, the currents in the upper circulating layers reach the bottom of the atmosphere outside the tropics and flow as south-west and north-west winds polewards, while some of the air which thus reaches the Earth's surface is forced round by the trade-wind and blows towards the equator with it (see fig. 25). A whirling motion,[1] such as Davis represents,[2] would help to account for the marked persistence of the above westerly winds at the Earth's surface in temperate regions. We have not as yet, however, sufficient data to build up a really satisfactory mathematical theory of the atmospheric circulation as a whole.

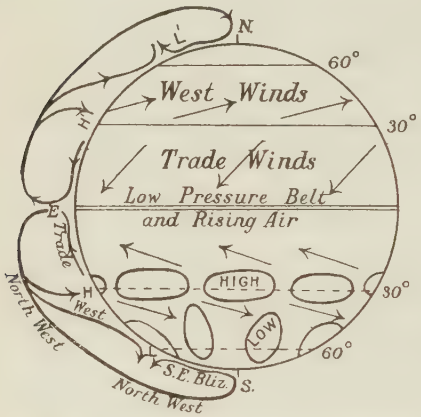



Fig. 25. Chief Features of the Planetary Circulation.

It has been suggested that the colour-belts on Jupiter indicate the difference between high- and low-pressure areas in that planet's atmosphere.

*Planetary circulation.* The Earth's planetary circulation, described above, may be represented thus :

A central belt of calms, which is really the region of ascending currents ;

Two wind belts, one north and one south of this ;

Two more belts of calms, at about 30° N. and S., really the

[1] To illustrate this take the example of water in a hand-basin with an opening at the bottom. If the basin is whirled round the water forms a whirlpool, becoming low in the centre and pushing up towards the sides of the basin where the water is piled up.

[2] See W. M. Davis, *Elementary Meteorology*.

regions of descending air-currents, and consequently high-pressure areas;

Two other belts of winds beyond.

Thus two distinct sets of winds, alike in the two hemispheres, are immediately due to the planetary circulation:

1. The trade-winds, blowing within the tropics;
2. The westerlies of the temperate zones.

To the same system belong the three belts of calms.

No more vivid description of the doldrums, or equatorial belt of calms, is needed than that of Coleridge:

> Down dropt the breeze, the sails dropt down,
> 'Twas sad as sad could be;
> And we did speak only to break
> The silence of the sea!
>
> All in a hot and copper sky,
> The bloody Sun, at noon,
> Right up above the mast did stand,
> No bigger than the Moon.

There is a great contrast between the dull heavy feeling of the doldrums, where the sea is often grey, like glass, from the reflection of the cloudy sky, and the brisk freshness of the trade-wind belt, where the sea is roughened by the wind and gleams with a denser blue than the sky itself. The trade-winds, so called on account of their steady flow, blow with great regularity within the tropics towards the equator. As they come from regions of less velocity, they are, at the equator, moving more slowly than the earth itself, and so become deflected and blow from north-east and south-east. The fact that they do not blow with equal force all the year round is due to the inclination of the earth's axis, which causes the sun's rays to fall unequally within the tropics; on a planet with a vertical axis this variation in their force would not occur.

North and south of the trade-wind belts are the sub-tropical high-pressure belts. Here the movement of the air is vertical, as in the equatorial belt, but in the sub-tropical belt the movement is downwards instead of upwards. Increase of pressure in the atmosphere causes these belts to be dry and not rainy;

in fact, their position more or less marks the desert belts of the Earth's surface. Beyond these, in the temperate zones, are the regions of the westerlies.

The prevailing westerlies, really west-south-west in the northern hemisphere and west-north-west in the southern, are winds of varying force, due also to convection and the Earth's rotation combined. They are more variable both in strength and direction than the trade-winds; in fact, it is only by keeping a careful record of wind-directions over long periods that one realizes the fact that they really blow, on an average, five days out of seven. The reason of their varying force is that they

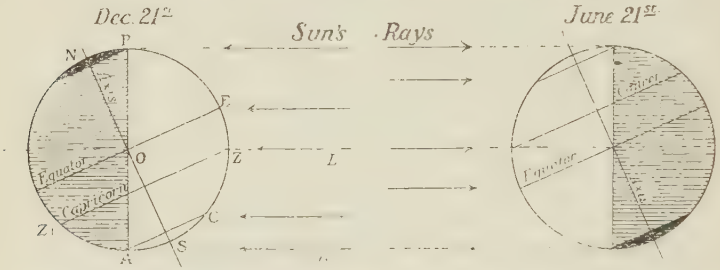



Fig. 26. Showing the effect of the inclination of the Earth's Axis on Insolation.

are constantly upset and even reversed by what are really minor disturbances, which will be dealt with later.

Having now seen what surface currents of air should obtain on any planet, we must next see what is actually the case on this planet.

*Terrestrial, combined with continental, influences produce periodical winds or monsoons.* Our planet differs, at any rate from some others, by having its axis inclined to the plane of its orbit. For this reason, the Sun, instead of being always directly overhead at the equator, appears to take a diagonal course from tropic to tropic, and is therefore overhead at each tropic once a year, and at the equator twice[1] (fig. 26).

The immediate result of this as regards the air's circulation is to upset the regularity of the trade-winds.

[1] Demonstrate to class by means of india-rubber ball and hat-pin.

In June, when the Sun is overhead at the tropic of Cancer, the equatorial belt of calms is shifted and the south-east trade-wind blows across the equator, becomes deflected in consequence, and forms a south-west wind. The north-east trade-wind at this time is partly broken up, but its influence begins further north, over lands which in winter are within the region of the westerlies (see fig. 27).

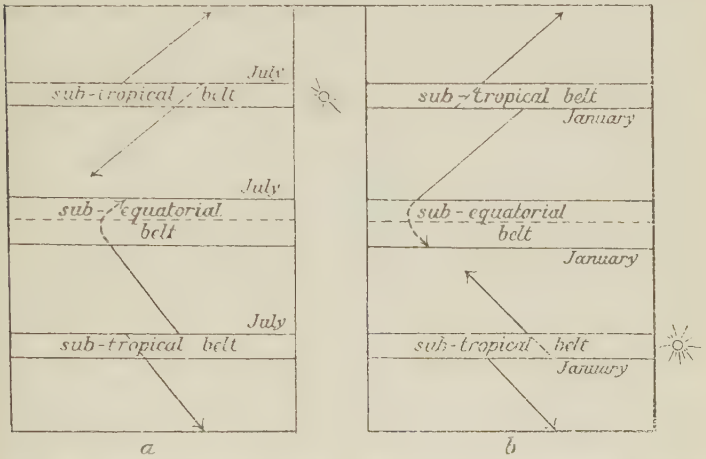



Fig. 27. Diagram of Periodical Winds showing alternating pressure belts and wind belts, also the invasion of the pressure belts and deflection of the winds during (*a*) the northern summer, (*b*) the southern summer. The approximate position of the Sun is indicated.

Conversely, in December the north-east trade-wind blows across the equator and the south-east trade arises further south than at other times.

This shifting of the belts would be of little importance if it were not that its effects are so enormously exaggerated by the irregular disposal of land and sea in the two hemispheres.

The winds arising simply from the shifting of the hot belt have been classified as 'terrestrial' winds—i. e. belonging to the Earth especially, of all the planets—and those due to land and sea distribution as 'continental', but it seems confusing to separate into two classes what really, in this case, constitutes one wind; it would therefore be well to restore Dove's classifica-

tion and to call them 'periodical' winds, their chief manifestation being in the form of 'monsoons'.

To make this point quite clear, it is necessary to state the case of the monsoon more fully.

When we have adjacent land and water areas, the unequal heating of the two gives rise to a secondary, or local, set of convection currents which, in some cases, reinforces the conditions otherwise obtaining. This happens particularly in summer in land-locked water-areas, and the most remarkable of these is the Indian Ocean (fig. 28). The Sun being overhead at the tropic of Cancer, the area of greatest ascensional movemement is shifted in that direction, so the south-east trade-wind blows across the equator, becoming then a south-west wind. The land being now greatly heated, a powerful indraught over it is created and the wind is drawn inland off the sea, mainly in the direction in which, owing to terrestrial causes, it is already blowing. This south-west wind from the ocean is moisture-laden and yields rain where it is forced upwards by the land, i.e. on the west coast of India by the Western Ghats and near the Himalayas, on the windward side. It really splits into two branches round India, one crossing the Western Ghats and the other passing up the Bay of Bengal; part of this latter branch, drawn westward towards the indraught from the heated area and forced westward by the Himalayan wall, passes up the valley of the Ganges. The extreme significance of this wind is due to the fact that to it India and adjacent lands are indebted for their abundant rainfall. In parts where the wind is not forced upwards and in parts which lie to leeward of mountains, as the Dekkan and Tibet, there are more or less desert regions. Blowing inwards towards the centre of Asia, this same wind becomes the south-east monsoon of the Pacific coast and, passing over the Yellow and Japan seas, brings rain to China and Japan.

The monsoons also greatly assist the rainfall of the Malay Archipelago, New Guinea, and the northern part of Australia, where adjacent land and sea conditions similarly prevail. In the Amazon basin they have the effect of enormously increasing the navigability of that river both in winter and summer. During

the southern summer the excessive precipitation of the equatorial hot belt fills the southern tributaries, whereas at the northward swing of the doldrums in July the northern tributaries are filled. Thus nearly all the year round there is excessive rainfall in the Amazon basin. A similar effect to that of the monsoons is produced, on a small scale, in the land-locked Gulf of Mexico, and, there being no high land-barriers for a long way to the north, the beneficent effect of the warm moisture-laden wind is felt far inland, where the United States would otherwise have suffered from drought.

When the hot belt has shifted south, the north-east trade-wind crosses the equator and becomes a north-west monsoon.

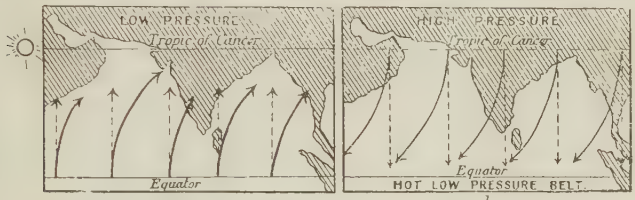



FIG. 28. (*a*) The South-west Monsoon in the Indian Ocean, blowing during the northern summer. The position of the Sun is shown overhead at the tropic of Cancer. (*b*) The North-east Monsoon blowing in the same area when the Sun is overhead at the tropic of Capricorn, during the northern winter.

This blows from sea to land in South America, Africa, and Australia, but it has far less force than the south-west monsoon described above, because there is less extent of land and consequently a very slight indraught. The wind here is unimportant except as regards navigation, and is due more to the swing of the doldrums than to the land and sea distribution.

At this time winter prevails in the northern hemisphere, so the sea is warmer than the land and a dry wind, blowing from land to sea, constitutes the north-east monsoon (fig. 28, *b*). The rain which now falls on to the western slopes of Ceylon and South India, coming from the north-east, is generally ascribed to this, but is really due to the retreating south-west monsoon.

During the northern summer the northern sub-tropical belt falls under the influence of the trade-wind and becomes a dry region, because the wind blows from land to sea and from

a cooler region to a warmer. In winter the westerlies hold sway in the northern sub-tropical belt and bring rain with them. The Mediterranean region is typical of these conditions.

*Other periodical winds.* Other winds of periodical development, but of quite local influence, are sea and land breezes and mountain and valley winds.

Sea and land breezes occur more or less on any coast (fig. 29). The underlying cause is temperature differences arising from, in the one case, the contrasted effect of sea and land on temperature; in the other, the effect on temperature of elevation above sea-level.

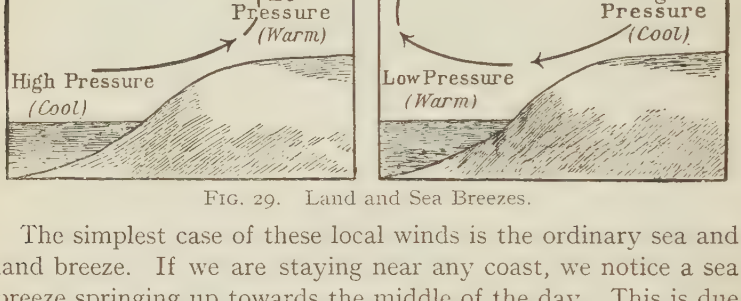



Fig. 29. Land and Sea Breezes.

The simplest case of these local winds is the ordinary sea and land breeze. If we are staying near any coast, we notice a sea breeze springing up towards the middle of the day. This is due to the rapid heating of the land, which thus becomes a low-pressure area, drawing in air from a region of higher pressure over the sea; it is in fact a monsoon in miniature, apart from any idea of direction. This sea breeze is replaced by a land breeze in the evening, caused by the rapid cooling of the land. The sea remaining warm, the pressure over it is lower than that over the land and the wind sets in its direction. We notice that the breeze is due to difference in *rate* of cooling rather than to differences in amount of heat lost or gained.

Similar breezes or winds occur in mountainous districts and are called mountain and valley breezes. They blow down from the mountains to the valleys at night and up from the valleys to the mountains during the day.[1] The night wind is explained

[1] The 'vent du Gemmi' literally blows one up the pass from Loèche-les-bains in the morning.

in a similar way to the land breeze (see above) ; it is, moreover, helped by the downward slope, the heavy cold air naturally falling from higher to lower levels. The day wind is not so easily explained. Other special winds mentioned in geography books are mainly of this local type, modified by the topography.

## X. Variable Winds

*Variable or cyclonic winds.* Within the tropics, as we have seen, the planetary system of winds is the prevailing one, this being *regularly* interfered with by winds due to terrestrial and continental causes combined. In addition to these regular interruptions, there are also occasional and *irregular* ones, whose existence one can readily understand if one considers how great at times must be the disturbances in such highly heated areas.

*Tropical cyclones due to convection and rotation.* This set of winds is of a stormy type and is traceable to local convection currents, stimulated by a whirling motion due to the earth's rotation. That the Earth's rotation plays a leading part in these tropical cyclones seems clear from the fact that they do not arise near the equator, because there the deflection is not sufficient to produce a whirling motion. They seem, however, to be certainly caused in part by convection, as cirrus clouds, due to condensation, have been seen streaming upwards from the centre. These cyclones are most usually found near the edge of the hot belt as it approaches the tropics in its annual swing. Tropical cyclones must not be confused with temperate cyclones, the cause of which has not yet been satisfactorily explained. The whirling motion has caused these two types of stormy movements to be named alike, but they may have little else in common, as modern research tends to show that convection does not play a leading part in the temperate cyclone.

Tropical cyclones move along a curved path and often leave destruction in their wake. In their centre may be a small patch of blue sky, known as the eye of the storm. They have been variously called according to the part of the world where they

occur : typhoons in the Chinese waters, hurricanes in the West Indies, tornadoes in America, also whirlwinds and simoons.

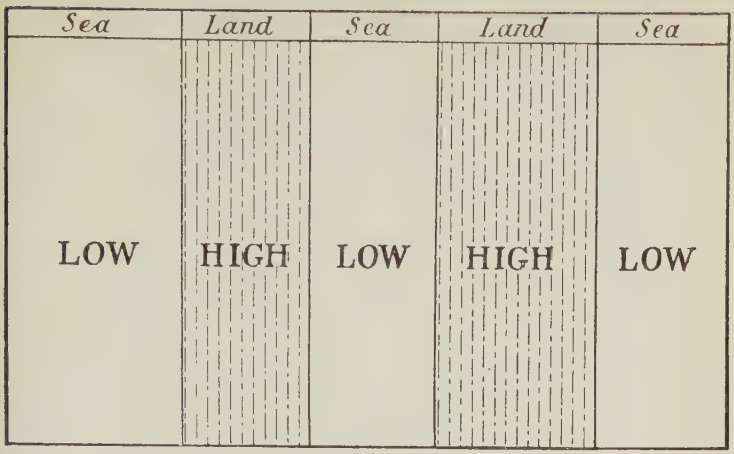
Hitherto the winds dealt with have been convection currents traceable to different modifying influences, but all having the Sun as their initial cause ; we now turn to winds of another kind, whose origin is far from being understood, but whose importance is vast, seeing they are the rain-bearers of the main land-regions of the world.

*Temperate cyclones.* It was seen (page 55) that changes of pressure occur owing to the different heating of adjacent areas, and that the difference in amount of heat received depended on the nature of the substance receiving it. It is necessary to enlarge on this point in order to understand the remaining and most difficult type of wind : the temperate cyclone. In considering this question we confine our attention to that part of the world where temperature changes are marked, i. e. the temperate zones. In tropical regions this factor can be disregarded, as there are no marked temperature changes.

Of the two temperate zones, the north has been the most studied, as many meteorological stations have been established there in the land-areas. The south temperate zone has the heaviest cyclones, but the data we have are insufficient to enable us to make definite statements with regard to its general atmospheric variations.

Before considering the winds of the north temperate zone at all, we have to realize that stationary conditions here are not almost uniform, as in other regions of the globe. The zone consists of alternating strips of sea and land. In winter the land is a region of high pressure, owing to its extremely low temperature as compared with that of the ocean. Over the ocean the air is warmer and tends to expand, so becoming lighter ; it also contains water-vapour, the condensation of which produces heat, rendering it lighter still. Hence the ocean is a low-pressure area in winter.

In summer, the land being greatly heated, the air expands and a low-pressure area is formed ; over the sea, on the contrary, the air is cool and the pressure, consequently, high.



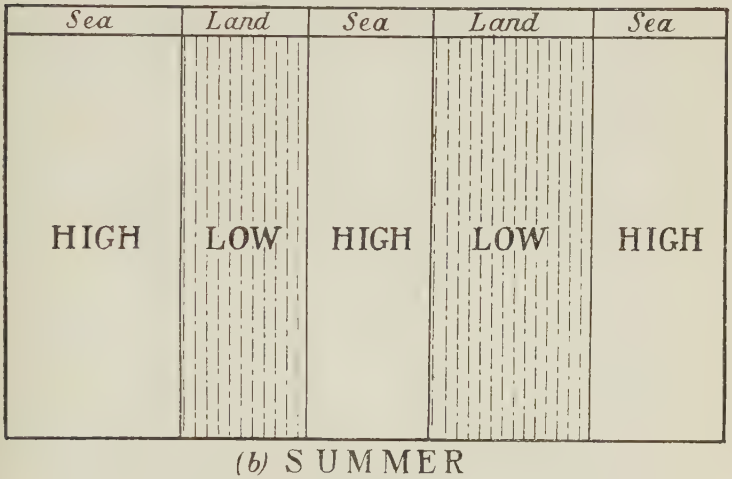




FIG. 30. Normal position of High- and Low-Pressure Areas over alternating strips of sea and land : (*a*) in winter ; (*b*) in summer.

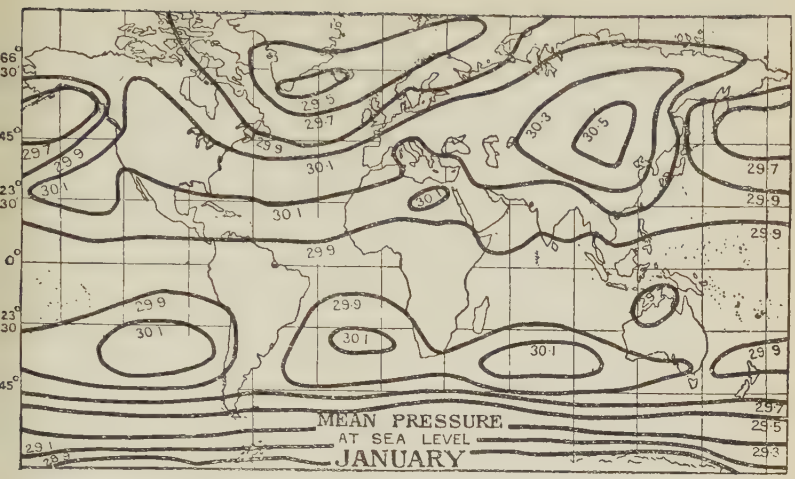
If we look at a map (fig. 31) showing the actual position that these areas may take up, we see that in *winter in the northern hemisphere* (fig. 31, *a*) there are greatly chilled high-pressure areas

over the land with corresponding low-pressure areas over the sea, these being all slightly shifted in an easterly direction as in the case of the isotherms.

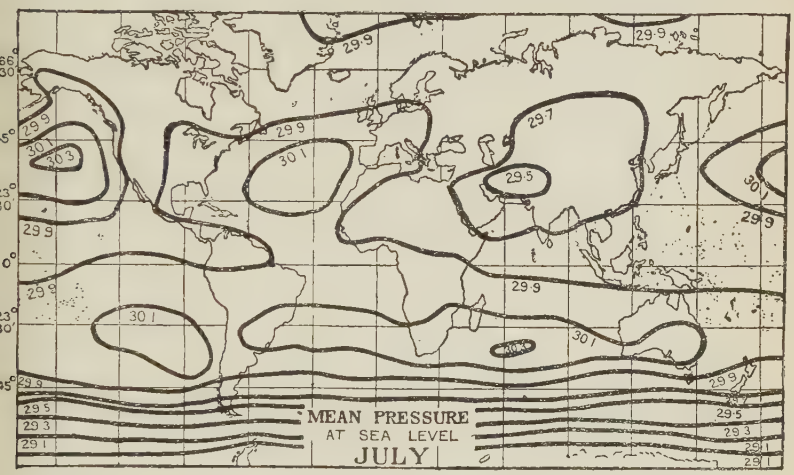
In the southern summer (shown on the same map), the land-areas, though small, become greatly heated, so we have the characteristic summer conditions of low-pressure areas over the land and high over the sea.

Similarly, when it is *summer in the northern hemisphere* (fig. 31, *b*), we find greatly heated and consequently low-pressure areas over the land, considerably shifted to the eastward, so that the North American land climate has its centre near Greenland and extends partly across the North Atlantic Ocean. The other main low-pressure area of the northern hemisphere has its centre in southern Asia. The corresponding high-pressure areas are near the Pacific coast of North America and near the coast of Spain and Africa.

Winter conditions in the southern hemisphere do not show characteristic regions of high and low pressure, because the large extent of the sea tempers the cold of the small areas of land, and there is not sufficient land to make a characteristic land climate in contrast to an ocean climate. High-pressure land-areas exist to a limited extent in South America, Africa, and Australia, but, for the rest, the ocean, having become a high-pressure area within and near the tropics in summer, parts with its heat so slowly that, having practically no contrasting land, it remains an area of high pressure throughout the year, the pressure diminishing gradually towards the Antarctic Circle. Thus the winter conditions of the southern hemisphere allow the planetary system of winds to hold sway as in other than temperate areas. More detailed maps show that the following pressure systems remain practically permanent all the year round: (1) The Iceland low; (2) the Alaskan low; (3) the Indian low; (4) the Antarctic circle low; (5) the Siberian high; (6) South Polar high. These definite high- and low-pressure areas would be central over land and sea on a stationary earth, but the whole system is spinning from west to east and so we get the shifting.




*a*




*b*

FIG. 31. Positions of High- and Low-Pressure Areas: (*a*) in winter; (*b*) in summer. Compare carefully with fig. 33. Note that the alternation shows far the best in the northern hemisphere, where land interference is greatest.

These so-called 'highs' and 'lows' are of great extent and long duration, but round their edges are masses of more rapidly moving air. These marginal disturbances are now thought to be of the nature of eddies and constitute, in themselves, smaller high- and low-pressure areas. They are specially marked in winter in the north temperate zone and are therefore not merely convectional, as convection is greatest in summer. It has been observed that in North America the most usual path of these disturbances is along the edge of the sub-tropical high-pressure belt. It may well be that in this region the crowding of different air-currents against the margin of the high-pressure area [1] and the friction of the continents produce a series of whirl within whirl, like the eddies in a river caused by irregularities in its bed. These eddies, which are frequently accompanied by rain, driven along by the constant winds—the westerlies—follow roughly an eastward path, so that an observer standing above the pole might see a continuous procession of cloud-sheets circling round the horizon.[2]

Clearly we have to deal with two different phenomena :

1. The large semi-permanent areas of high and low pressure ;
2. The complex movements of the streams of air that characterize their margins.

The term 'cyclone' was first applied to the smaller marginal depression, and later the word 'anticyclone' was invented to designate the opposite condition, i. e. high pressure. The latter word has, however, been applied to both kinds of high-pressure areas indiscriminately : the large stationary one, which occupies a semi-permanent position over sea or land, according to the season, and the smaller, which is of the nature of an eddy. This uncertainty of designation has caused confusion, so, in the present work, the terms cyclone and anticyclone will be restricted to the disturbances taking place *within* the wider areas.

The movements of these marginal eddies of the stationary

[1] The sub-tropical high-pressure belt forms, according to Davis, the rim of the north polar whirl.

[2] The Australian anticyclones are very regular in occurrence. Each travels across Australia in rather more than a week, there being about forty-five in the year. For a description of these see Griffith Taylor's *Australian Meteorology*.

areas are of the utmost importance in determining weather in the north temperate zone, and for this reason constant readings of the barometer are taken. In order to represent the changing conditions of the atmosphere, a number of simultaneous readings are plotted on a map, and so the exact position and extent of the low- and high-pressure areas at that time are marked out. Lines called isobars are drawn on the map connecting the places where the pressure, when reduced to sea-level, is the same, and these reveal the fact that the areas are usually more or less oval in shape. A succession of maps of this kind shows the movements of cyclones and anticyclones from day to day, and by means of these scientific weather-forecasting is carried on (figs. 32 *a* and 32 *b*).

Considering first the cyclone, as being the main disturbing factor in the weather, we find that it has a more or less definite structure. Broadly speaking, it is a centre for inflowing winds from the high-pressure regions outside. One would expect these winds to flow inwards towards its centre, but the Earth's rotation prevents their direction from being radial and gives them a rotary movement; they flow therefore more or less nearly parallel to the isobars, but slightly inclined towards the centre. In the northern hemisphere their direction is anti-clockwise, and in the southern hemisphere clockwise. To express it briefly, in the northern hemisphere the cyclonic wind takes practically the path of a left-handed screw, the axis being more or less nearly vertical in direction.

The connexion between the direction of the wind and the falling or rising barometer is expressed thus in Buys-Ballot's Law: 'Stand with your back to the wind and the barometer will be lower on your left hand than on your right. In the southern hemisphere, on the contrary, it will be lower on your right hand than on your left.'

If a cyclonic area is roughly plotted on a map, as in the diagram fig. 32, we can tell the probable direction of the wind in each part and, by the distance of the isobars from one another, we can judge of its speed. If the isobars are near together the gradient or change of pressure per unit of distance is great and the wind is therefore strong.

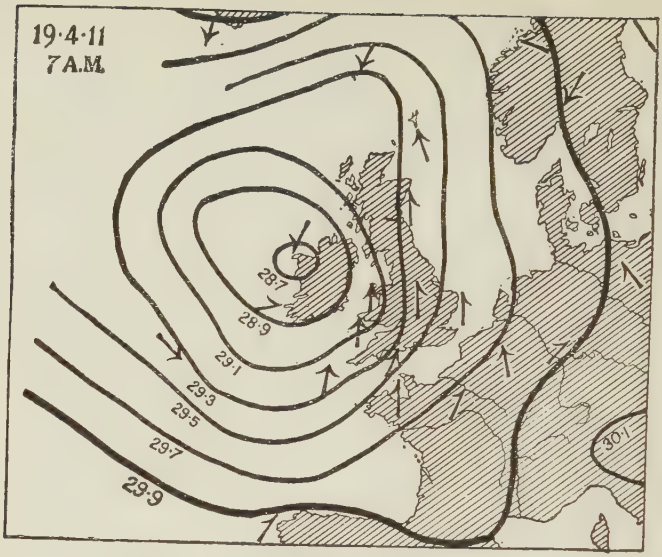



FIG. 32 *a*. Low-Pressure System or Cyclone.

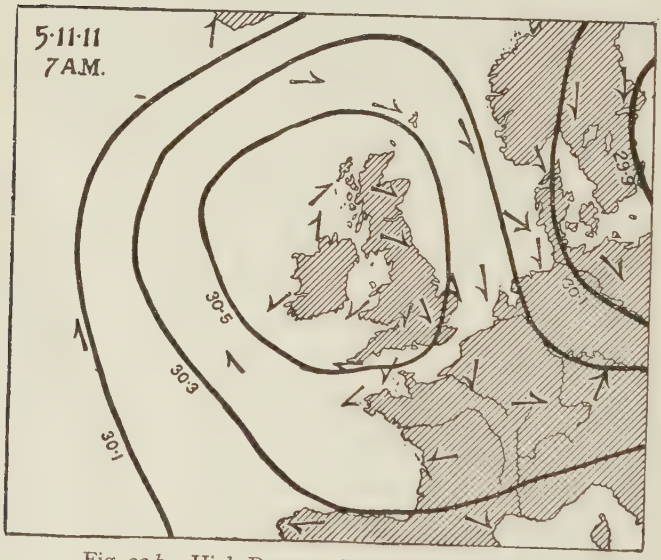



Fig. 32 *b*. High-Pressure System or Anticyclone.

A diagram of a cyclone and its parts is represented in fig. 33.

The whole depression is usually oval in shape and may spread over an area of several hundred miles; it does not extend far from the bottom of the atmosphere, and is disc-shaped, having a vertical thickness of only four or five miles. It moves near the British Isles most commonly in a north-easterly direction along its path—represented in the diagram by an arrow—and is probably carried onward by the prevailing south-west currents of higher altitudes. Across its centre, at right angles to the path is the 'line of trough', where the barometer reaches its lowest for any line parallel to the path of the cyclone.

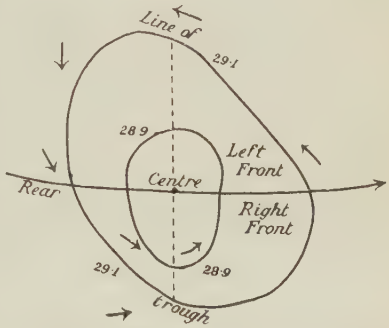



FIG. 33. Diagram of Actual Cyclone showing its parts. Note the closed isobars and direction of winds. The barometer is falling at places in front of line of trough, but when that has passed it is rising.

Near the centre is an area of rain, surrounded by a cloudy area, both cloudy and rainy parts extending further to the front than to the rear. In the front is warm, muggy weather with a dirty sky; to the rear the weather is brisk and cool and the sky clear. So the trough divides the cyclone into two well-defined parts, places in front of the trough having a falling barometer and places behind it having a rising barometer as the cyclone passes over.

To account for rain in more than one part of the cyclone, we have to analyse it still further:

The almost circularly moving wind can be divided into:

1. An east wind on the north;
2. A west wind on the west;
3. A wind on the south side veering from south-east to south.

This can be represented as in fig. 34.

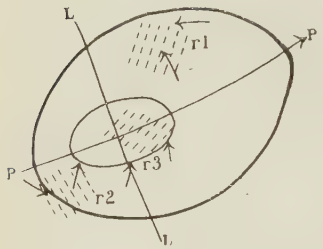



FIG. 34. Diagram showing Position of Rainy Areas in a Cyclone.

$r_1$ and $r_2$, rain caused by air-currents crossing.

r3, rain due to conveyance of currents.

In the case of $r_1$ we have the shouldering up of warm air by a cold easterly current, which produces fitful showers. In $r_2$ we have the displacement of warm south-west or south winds by a cooler wind from the west, producing heavy showers. In $r_3$, which stretches sometimes from the right front quadrant to the left back quadrant, there is a steady, uniform rainfall. P represents path of cyclone, and L line of trough. (After Shaw, Abercromby, &c.)

The warm air from the south is driven over the barrier of cold east wind, while the cool air from the west passes under it. Rain is therefore due to :

1. The passing of the warm air over the colder east current ;

2. The passing of the cool west wind beneath the warm south ;

3. The convergence of warm winds from the south.

It is believed that the actual meeting of the currents of different temperatures is sufficient to produce cloud but not rain ; the rapid whirling motion, which in a cyclone is added to this, seems to be the direct cause of rain.

As the cyclone passes across the Atlantic Ocean, its approach to our islands is always marked by a falling barometer and often by a rising wind.

Each cyclone is usually accompanied by an anticyclone a little to one side of it. Thus the weather in the temperate zone is due to the passing of a rapid succession of cyclones and anticyclones of varying size and intensity, borne by the upper air-currents in a more or less east-north-east direction.

In the anticyclones, the pressure being high, the wind flows outwards from the centre and, at the bottom in the northern hemisphere, the twist given it by the Earth's rotation sends it in a clockwise direction (fig. 35).

As in the case of the cyclone, the direction actually taken by the wind, owing to this twist, is more or less nearly parallel to the isobars, only that as they travel outwards the winds become dissipated and lose their force, so the presence of an anticyclone

is usually an indication of gentle breezes and fine, calm weather. When an anticyclone is stationed over the North Atlantic Ocean, the air blowing outwards from its centre usually produces a north-west wind in the British Isles, veering to north-east as it passes eastward and giving fine weather.

Sir Napier Shaw points out that there is another kind of anticyclone, which is a practically isolated and, for the most part, inert mass of air, covering a large region and remaining stationary for long periods, such as the anticyclone that prevailed over western Europe in the summer of 1911. This kind of high-pressure system is really complex in itself and may be accompanied by almost any type of weather except one of swift and violent changes.

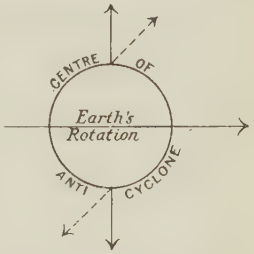



FIG. 35. Deflection of Wind's Direction in Anticyclone.

*Theory of cyclones.* Hitherto what is known as the 'Convection Theory', given above to explain tropical cyclones, has been considered to account adequately for all cyclones alike; this has led to great confusion and has also retarded research with respect to temperate cyclones. It was supposed that a central ascending current, on reaching higher levels, flowed outwards in all directions and, on cooling, sank once more to sea-level, thus producing anticyclones. So, according to this theory, in the upper layers of the moving air the cyclones fed the anticyclones and, in the lower layers, the cyclones were reinforced by the anticyclones. In accounting for tropical cyclones, this theory seems satisfactory enough, for convection obviously takes place in these, the rising currents in the higher layers sometimes becoming visible as feathery cirrus clouds streaming upwards. In the case of temperate cyclones, however, this theory fails to account for:

1. The great frequency of the cyclonic disturbances in the North Atlantic Ocean;

2. The fact that the cyclones are most common in the colder half of the year;

3. The distribution of temperature in the cyclone, as it seems probable that, in the temperate cyclone, this is relatively low in the centre. The cyclone, as a whole, is not a warm area, but the distribution of temperature is asymmetric, so that the centre of low pressure is nearly on the border between the regions of warm and cold air. It may even be that centrally the anti-cyclone is the warmer area of the two, but owing to the difficulty of gauging temperatures at high altitudes, this has not been conclusively proved, or, at any rate, no data have, as yet, been published.

The newer Dynamic Theory put forward by Shaw and Lempfert is based on our increased knowledge of the structure of a cyclone at different levels, due to the researches of M. Bigelow.[1] It does not necessarily override the theory stated above in describing the movements of cyclones in general, i. e. that they are eddies due to the impinging of different currents of air on one another and the crowding up against high-pressure belts. One theory is put forward more in America to explain the direction of the currents and the other is concerned with the intimate structure of each area. Both may be stepping-stones on the way to more exact knowledge.

In describing the structure of cyclones it is necessary to give some account of the dynamic theory to supplement what has been said above. According to it, the cyclone is not the first development and cause of disturbance, but differences in temperature of adjacent masses of air may furnish the energy for cyclonic movement. This movement once initiated, the tendency is for the barometric pressure to be lowered still further, so that the cyclone bears within itself the conditions favourable to growth. Bigelow, who has devoted much time to studying the movements of clouds, has traced the origin of the North Atlantic disturbances as being at a height of about 7,500 ft. above sea-level. This differs entirely from the Convection Theory, which

[1] Generalizations from Bigelow's observations of air movements in the North Atlantic present so many difficulties that so far we can only say the Convection Theory has failed, we cannot say that any new theory is satisfactorily established.

would place the origin quite near sea-level. By watching cloud movements, Bigelow discovered that, at the considerable height mentioned, the warm current of air rising from the Gulf of Mexico meets the cold current from the north, the two forming a *descending* eddy. The stronger this eddy is, the less is the pressure at middle point and the more, consequently, the barometer falls.

Thus, the North American cyclone resembles, in many ways, an inverted whirlpool, and, for simplicity's sake, Bigelow represents it as having a vertical axis, although the axis may be inclined.

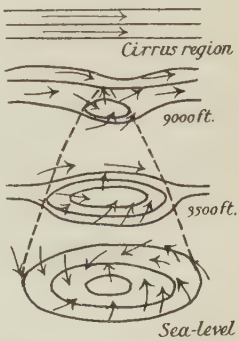



FIG. 36. Diagrammatic representation of a North American Cyclone at four levels. (After Bigelow.)

Bigelow's diagrammatic representation (fig. 36) shows the conditions prevailing at four different levels, one above another. The disturbance is seen to have the form of a cone, narrowing upwards, the vertical height in relation to the horizontal extent being, for purposes of convenience, greatly exaggerated.

The origin of the disturbance must be below the cirrus region, for in that region the clouds are seen to be drifting calmly and steadily from west to east, as they would under the influence of the planetary wind.

At 9,000 ft. altitude, the disturbance is beginning to manifest itself by a slight circulatory movement around a centre where the tendency is for the air to flow upwards. This is the centre of the inverted whirlpool.

At 3,500 ft. the upward flow of air in the centre is still seen. The vortex has widened out and the wind has a definitely cyclonic movement to the west and south, but the outward flow in front of the cyclone still continues and the north side has not yet been drawn into the movement, this being of unequal all-round development.

At sea-level we see true cyclonic conditions, the whole of the surrounding air at that level being drawn into the movement

and flowing inwards from all directions, taking an anti-clockwise and spiral course except in the centre, where it passes vertically upwards.

The changes and disturbances in the atmosphere of this part of the world, i. e. the North Atlantic Ocean and its bordering continents, have been studied more fully than elsewhere, as the climates of the whole of North America and western Europe

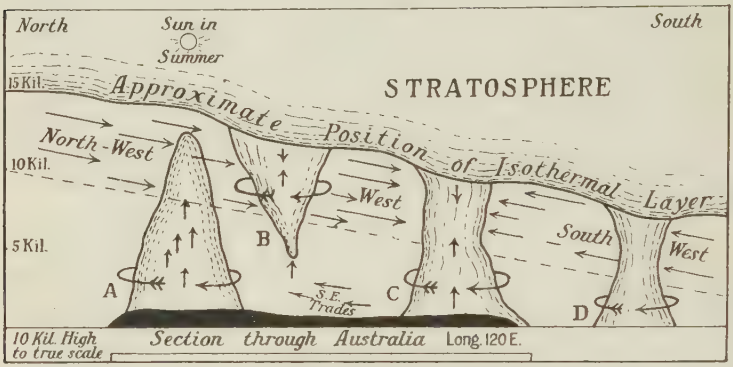



FIG. 37. Generalized diagram (vertical section along 120° E. long.) illustrating the formation of Eddies in the upper air of North Australia. (After Griffith Taylor.) A is a convection dome (at Pilbarra) building up under the midsummer sun. B is a young tropical low formed in the north-westerly drift by the action of the convection dome. It may only affect the surface isobars as a loop, but may give good rains owing to the updraught. D is an Antarctic low coming from the south-west, and formed of relatively dense air. C The tropical and Antarctic lows have fused to form a strong rain-producing low. It moves along in the westerly drift.

N.B.—The vertical scale is exaggerated sixty times. The true scale is indicated at the foot of the diagram.

are affected thereby and these countries contain or control most of the large markets of the world.

Griffith Taylor, in his book on *Australian Meteorology*, claims for tropical cyclones also their initiation in the upper air, the disturbance in this case being due to the interference of a convection dome which, built up by the intense heat of the Sun, comes into contact with the north-westerly drift, so that an eddy forms in the vicinity of the dome. A tropical 'low' thus produced (B in fig. 37) and carried southward by the drift, may

come into contact with a ' low ' similarly produced near the Antarctic convection dome but proceeding northward, in which case a strong rain-producing area will result. Griffith Taylor puts forward the ' convection dome ' theory tentatively, as satisfying well-marked local conditions, and it is possible that the comparative non-intervention of contrasting sea and land-conditions in the southern hemisphere may enable us there first to obtain a clue to the more perplexing conditions in the north.

## XI. Distribution of Temperature as affecting Climate

*The Chief Climatic Regions.* In Chapter IV we considered the Earth's relation to the Sun, and deduced therefrom the laws governing the insolation or solar climate ; the other causes influencing climate were dealt with under the general heading of ' The Atmosphere '. We now see that in spite of the disturbing factors therein described, the solar climate is of first importance, and the insolation zones form the bases of the chief climatic regions.

Our examination of solar climate showed us that the greatest heat prevailed at the equator near the equinoxes, and near the tropics at the solstices. Also that the heat decreases regularly polewards at the equinoxes, but not at the solstice in the hemisphere in which it is summer.

*The Climatic Zones.* The solar climate corresponds to the old climatic zones, and this kind of climate would prevail altogether

(i) if the Earth's surface were of uniform material, i. e. all land or all sea,

(ii) if the surface of the land were as level as that of the sea.

As it is, the solar climate gives us a certain established basis, the actual or physical climate presenting certain modifications of that basis.

The division into climatic zones seems to have been made very early, even in the time of the ancient Greeks. Vergil's picturesque description of these zones is worth quoting : ' Five zones embrace the heavens, whereof one is ever glowing with the bright sun and

scorched for ever by his fire ; round which the two farthest ones to the right and left are extended, stiff with cerulean ice and horrid showers. Between these and the middle zones, two, by the bounty of the gods, are given to weak mortals.' [1]

Ptolemy, later, tried to fix the breadth of a 'klima' or zone by the difference in length of the longest day. In modern times it has been customary to make special lines of latitude limit the zones, the lines, in fact, which mark the tropics and the Arctic and Antarctic circles (i. e. $23\frac{1}{2}^\circ$ from the equator and poles respectively).

If, instead of choosing lines of latitude to bound the zones, we separate them by means of isotherms, which are affected by land and sea conditions, we can divide the Earth into the true thermal zones and yet keep, practically, to the simplicity of the old five zones. Supan was one of the first to do this. In his map (see fig. 38) the Hot Belt or Torrid Zone is all the part enclosed by the mean annual isotherm 68° F., and he separates the Temperate zones from the Frigid by the isotherms of 50° for the warmest month. See and compare figs. 17, 19, and 20 (above). Other thermal zones have been suggested.[2]

Supan, Köppen, Herbertson, and other writers further subdivide the zones into Climatic Provinces,[3] but the consideration of these is not within the scope of the present work. To obtain a broad general idea of Climate is of the utmost importance, and to this end it is best to view the matter only very broadly at first. It, therefore, suffices here to treat only of the five zones and their main characteristics, where necessary dealing with land and water areas apart from one another.

*The Torrid Zone.* The so-called 'Torrid Zone' or 'the Tropics' [4] will be considered as bounded by the mean annual isotherm of 68°, rather than, arbitrarily, as the part extending $23\frac{1}{2}^\circ$ north and south of the equator. This region is remarkable for the uniformity of its climate and the regularity of the weather

[1] Davidson's translation of *Georgics*, i. 233–9.

[2] Herbertson, *The Thermal Regions of the Globe.*

[3] See Bartholomew's *Atlas of Meteorology*. See also Ward's *Climate*.

[4] This is a very bad term, unfortunately in common use for inter-tropical.

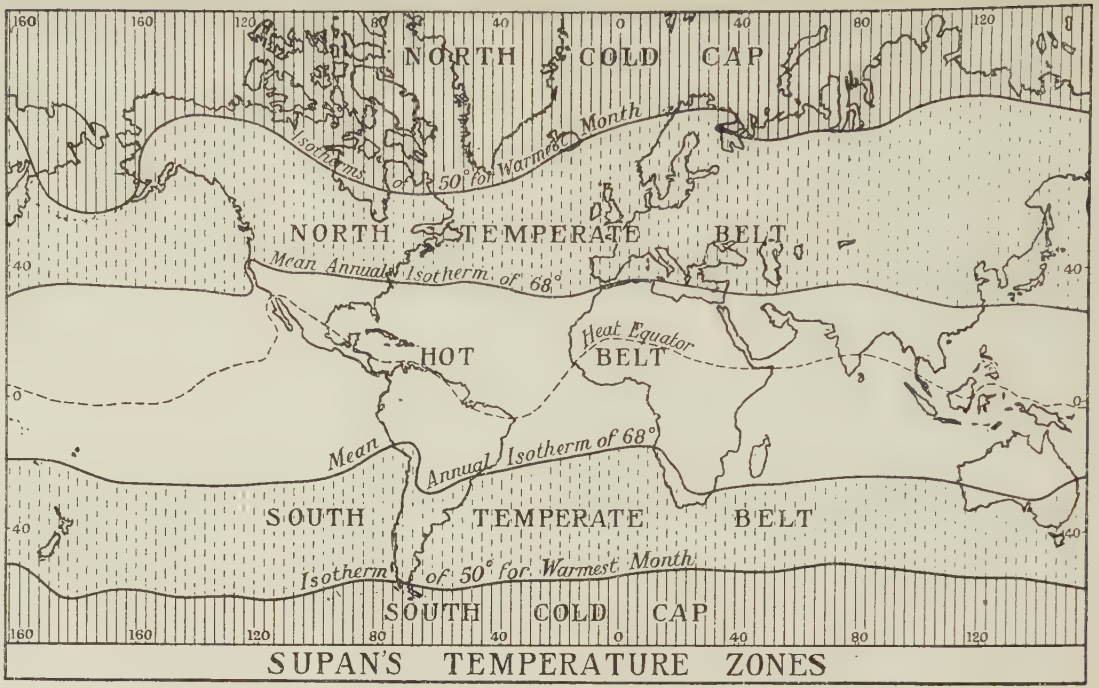

160
120
80
40
0
40
80
120
NORTH COLD CAP
Isotherm of 50° for Warmest Month
NORTH TEMPERATE BELT
Mean Annual Isotherm of 68°
HOT BELT
Heat Equator
Mean Annual Isotherm of 68°
SOUTH TEMPERATE BELT
Isotherm of 50° for Warmest Month
SOUTH COLD CAP
SUPAN'S TEMPERATURE ZONES

FIG. 38.

sequence. Storms are very rare, but when they do occur their violence is such as to leave devastation in their wake. By far the greater part of this zone is a water-surface, and here the range of temperature is so slight as to be not much more than 5° in the year. There are no seasons in our sense of the word, although the rainy season is sometimes called winter, because the cloudiness of the sky renders it somewhat cooler.

The equatorial, or central part of this zone, is a region of excessive rainfall, for the hot air, rising into cooler regions of the atmosphere, loses its heat by condensation. This is the ' belt of calms ' dreaded by the sailor on account of the difficulty of crossing it in the old days of sailing vessels. Nowhere has it been more graphically described than by Coleridge in *The Ancient Mariner,* although the description in its details is almost too gruesome :

> The very deep did rot : O Christ !
> That ever this should be !
> Yea, slimy things did crawl with legs
> Upon the slimy sea.
>
> About, about, in reel and rout
> The death-fires danced at night ;
> The water, like a witch's oils,
> Burnt green, and blue, and white.

The only parts of this central belt that consist of land are the Amazon basin in South America, the Congo basin in Central Africa, and the Malay Archipelago ; these are all characterized by the extraordinary density of their vegetation. They enjoy a double rainy season for the most part and the so-called dry seasons are never wholly rainless.

To the north and south this Central Equatorial Belt merges into the Trade-wind Belts. Here, over the sea, the constant direction of the wind, always moving towards an area of higher temperature with no disturbing factors, tends to prevent any fall of rain. But over the land the trade-wind sooner or later, in consequence of some disturbing factor, such as high ground, is forced to deposit its moisture, and then, for the rest of its course over the land, is a dry wind. Thus the N.E. trade-wind causes a heavy rainfall on the mountains of Abyssinia, but after that,

desert conditions across the Sahara. Similarly the S.E. trade-wind causes a considerable rainfall in S.E. Australia and desert conditions in the centre of that continent. In the northern part of South America the trade-wind meets only moderately high ground at first and then the high ranges of the Cordilleras. Consequently there is a considerable rainfall right across the continent. We have assumed that the trades blow steadily across these large land masses. This, of course, is not the case, and the direction of the wind is much influenced by the monsoon effects of the land masses. In the monsoon belt the land and sea type of climate overrides the other and we get a genuine 'Convection Climate'. In summer the land becomes so intensely heated that a warm moist wind from the ocean—the south-west monsoon—blows inland; in winter the cool north-east monsoon blows seaward except in the extreme north of India. This kind of climate characterizes the lands which fall under the influence of the Indian Ocean, and in India itself three seasons are known:

Winter, the cool dry season with north-east monsoon;

A hot dry season, before the rains;

A rainy season, due to the inflowing south-west monsoon.

The above description shows that throughout the Torrid Zone the same general conditions prevail, these being most uniform where the influence of the winds is least felt, i. e. in the equatorial part. There are, however, marked differences noticeable in passing from the equator to the tropics, so that the zone, when considered in detail, falls naturally into the following three divisions as already indicated:

(1) the equatorial belt,
(2) the trade-wind belt,
(3) the monsoon areas,

each showing certain modifications as sea or land predominates.[1]

*The Temperate Zones.* The climate of the temperate zones is far more difficult to define than that of the torrid. Many authors object to the name 'Temperate', seeing that the main

[1] De Courcy Ward, in his book on *Climate*, gives a fourth subdivision—Mountain Climate, but as this is subject to similar influences throughout the world it seems unnecessary to deal with it in each zone separately.

characteristic of the northern zone is lack of temperateness. It is, of all the zones, the most extreme as regards temperature variations.

The chief point to be borne in mind in considering the temperate zones is that here the difference between sea and land climates dominates all else. The South Temperate Zone is the more easily dealt with, since it is the marine type, practically undisturbed. The North Temperate Zone, on the other hand, is a most complete admixture of marine and continental conditions, the globe surface being composed of alternating masses of sea and land. Its climate has been described as a 'crazy quilt of patches'; patchy it is, but not crazy—there is method in its madness.

*South Temperate Zone.* Taking first the South Temperate Zone as most typical, we have here the simplest conditions, i. e. the purely marine type of temperate climate. Temperature changes are slight, as is usual over oceanic areas, the seasons are uniform, there are no great extremes of heat or cold. The westerly winds pursue their way uninterrupted by the influence of continental stretches. These winds are very variable in force and bring fairly frequent storms in their wake. The weather therefore depends on the frequency of the cyclonic disturbances and is regulated by them. Stormy conditions prevail more or less throughout the year, but are most frequent in winter. The strength and persistency of these winds across the broad oceanic area from latitude 40° southwards procured for them the name of the 'roaring forties'. In the days of the sailing vessel, the westward navigation of Cape Horn was the terror of sailors, and hardly less feared was the famous 'Cape of Storms' until King John of Portugal diverted the idea by changing its name to 'the Cape of Good Hope'. Continental areas in this zone are small and too narrow to affect the marine nature of the climate; consequently, cool summers prevail and the winters are moderate. Air movements being strong and vigorous, the climate is healthy, i. e. suitable for human occupation and enterprise. Most of the land is situated in the sub-tropical portion of the zone, and its climate should therefore be compared with the Mediterranean type, under which heading it will be more fully

described. As Supan's map (fig. 38) shows, the land-areas comprise the narrower part of South America including the rain shadow region of the central west, a very small portion of south and south-west Africa and the southern part of Australia, also Tasmania and New Zealand.

*The North Temperate Zone.* The climate of the North Temperate Zone is best understood by considering it under two headings: marine and continental.

Owing to the influence of the prevailing westerlies the marine type includes not only most of the ocean surfaces but also the western coasts of the continents; in fact, if the coast is low, it may penetrate far inland. The continental type includes the main part of the land-areas and stretches beyond the east coasts some way over the ocean. This arrangement is easy to understand, if we realize that both marine and continental climates are shifted eastward, just as the high- and low-pressure areas in the atmosphere were seen to be shifted.

The climate, then, over almost the whole area, depends on the distribution of sea and land, but near the southern edge of the zone the influence of the Torrid Zone is sufficiently felt to produce a definite modification of the ordinary type, which will be distinguished as the warm temperate belt.

*Marine type.* The marine type of climate in the North Temperate Zone has mild winters, cool summers, and abundant rainfall, mainly in winter. It is thus similar to the marine type in the South Temperate Zone, although it varies from that type in two main particulars:

1. There is a tendency for the winter temperature to be much higher than is normal for the latitude; this is the case particularly in the North Atlantic, and consequently the lands adjoining that ocean on its east side have remarkably mild winters. This tendency may be explained by the fact that the warmer waters are forced out of their normal course by land interference. On the Atlantic coasts and also on the corresponding ones in the Pacific, the temperature range is under 25° F., i. e. no greater than in some parts within the tropics.

2. Although these regions are within the path of cyclones, the

air-current is not so swift and vigorous, partly owing to the friction of the land, and consequently the disturbances are not so frequent and violent as in the southern hemisphere. This type of climate characterizes the oceans and extends over western Europe and north-west North America.

*Continental type.* The continental type of climate in the North Temperate Zone contrasts with the marine in every particular. It is of the most extreme type, i. e. the temperature ranges in the continental interiors, instead of being under 25° F., are as much as 150° F. in North America to 170° F. in Siberia. The rainfall is in summer instead of in winter, because in summer the cool moist wind from outside penetrates into the highly heated interior. The winters in these great land-areas are extraordinarily severe, and have the remarkable effect of facilitating intercommunication over the lower-lying lands instead of impeding it, for the rivers can then be crossed without bridges and the snowy surface is everywhere available for sleighing. This fact has influenced the history of Russia and is also of economic importance as regards the lumber trade of Canada. Not only is the climate extreme, but it is subject to sudden changes, due to the influence of cyclones. In spite of the winter severity, the hot, though short, summers with copious rainfall are very favourable to agriculture; these regions are, in fact, the great grain-growing districts of the world.

As has been stated above, this type extends to the east coasts of the continents and over part of the adjacent oceans. The east coast for this reason has sometimes a temperature range four times as great as that of the corresponding west coast. It differs in one respect from the continental interior, namely, that the rainfall increases from the interior eastward, because the wind does not blow continuously from the west, and at other times the influence of the eastward-lying ocean is felt. In North America there is no mountain barrier on the east, so that the differences in climate between places on the opposite sides of the Atlantic are the most striking known, although some slight modification of the extreme continental nature of the climate is due to the eastward-lying ocean.

*Warm-temperate type.* On the tropical margins of the temperate zones are belts more or less within the influence of both zones, temperate and torrid. These are put under a separate heading owing to the fact that they are climatically the most highly favoured regions of the world. In winter the climate of these belts associates itself more with that of the Temperate zones and there is a moderate rainfall, but this is interspersed with sunny intervening periods. In summer the climate assimilates itself to the more tropical type, so that dry and almost continual fine weather is enjoyed. These belts are not continuous round the world; in the northern hemisphere the belt corresponds with the very long east and west depression referred to in Chapter XII on 'Distribution of Land and Sea', of which the Mediterranean hollow forms part. The trough-like character of this depression tends to accentuate the climatic type, so that the belt is here very extensive, embracing the Mediterranean Sea with both shores and continuing into Mesopotamia, Arabia, and Persia. A smaller portion of it gives the delightful climate of California.

In the South Temperate Zone, Central Chile, the Cape Province of Africa, south-western and part of South Australia, and northern New Zealand occupy the warm-temperate belt.

These belts are characterized by abundant sunshine and by winter rains, but the latter do not bring continuously overcast skies. The temperatures are not extreme, and the lands happen to be particularly well sheltered by mountain ranges. Autumn is a good deal warmer than spring, as the high sea-temperature persists far into the winter. The sub-tropical belt, especially in the lands bordering the Mediterranean Sea, is subject to markedly hot or cold local winds at times, due partly to the conformation of the land. By these winds quite unseasonable temperatures are temporarily produced.

*Frigid or polar zones.* Of the climatic conditions of the two Frigid zones little, except their extreme cold, was known until recent years, owing to their unsuitability for human life. Taking temperature as the basis of their separation from the North and South Temperate zones, they are bounded on the map by the

isotherm of 50° F. for the warmest month. This line passes well north of the Arctic Circle in Asia and Europe, including only the extreme northern coasts of Siberia and Scandinavia, but it passes south of the circle in America, so that the whole northern coast to the southern shores of Hudson Bay and also the whole of Greenland come within the Frigid Zone. The line bends still further south over the North Pacific Ocean.

In Antarctic regions, this same isotherm runs practically due east and west, and includes within the zone the extreme tip of South America.

The climate of the two zones is, on the whole, similar, apart from certain individual variations due to the facts that the North Frigid Zone is mainly a water-surface surrounded by huge masses of land and the south a land surface encircled by immense stretches of ocean.

Although, during the summer in either Frigid Zone, the sun is above the horizon for a much longer time than anywhere else on the globe, yet its rays fall so obliquely that their heat is not sufficient to reduce appreciably the amount of snow and ice that has accumulated during the correspondingly long winter. For this reason these zones have a very low mean annual temperature, the winters being excessively cold and the summers by no means warm. In latitude 70° N. the mean winter temperature, according to Hann, is about − 15° F. and the summer about 45°. In the southern zone, temperatures are never so high and the range is far less. Thus, in latitude 70° S. in July (winter) the mean temperature is about − 8° F. and the summer only about 30·6° F. The summer temperature, therefore, is actually below freezing point at that latitude, although the winter temperature is less low than in the north. Beyond 70° polewards the southern hemisphere is probably colder than the northern.

The explanation of these climatic differences is probably to be found in the contrasting disposition of sea and land in the two zones. The distribution is simplest in the South Frigid Zone, and therefore it will be best to consider this first. We imagine here that we have a central continental area, probably unbroken, surrounded by an ocean ring. The wide extent of this ring gives

an oceanic character to the climate far within the limits of the zone, thus inducing the slight annual range of temperature. The atmospheric pressure areas also seem to have a fairly simple arrangement in this region. Outside the zone, the so-called 'roaring forties' and 'shrieking fifties' constitute the circumpolar whirl, but, beyond these, the margin of the low-pressure area is soon reached and gives way to a high-pressure area, which is probably central over the pole in winter. This produces gentle outward-flowing winds which blow from the south, but are deflected by the Earth's rotation, and so become south-east or east winds. The seasonal shifting of this area is so definite that a vessel, the *Belgica*, which had been driven eastward all the winter, was found in summer to drift westward, because the influence of the westerlies was superseded. Though the actual south polar climate is supposed to be a calm one in the main, yet its margins constitute a belt of great cyclonic activity, resulting in violent winds and terrific snowstorms. It seems as if the force of these storms must penetrate further poleward than has been hitherto supposed, for it was at about 86° S. that Captain Scott and his brave comrades pitched their last camp. The diary mentions a 'long gale in 83°', and also that the fierce blizzard in which it was written had already prevented egress from the tent for four days.

The greater extremes of temperature which characterize the north polar region are due to the continental type of climate, which is induced, especially about its margins, by the fact that the Arctic Ocean is really only a land-locked sea. Probably, in the highest latitudes, this continental aspect is considerably lessened. A somewhat anomalous condition is introduced in a certain part of the zone, owing to the winds and wind-borne currents of the North Atlantic Ocean, which are warm and are diverted far north by the shore configuration. The climate of this portion of the zone, namely, the west coast of Greenland, is considerably less severe than it should be normally.

In the North Frigid Zone again, the ring-like arrangement of high and low pressure, which obtains in the atmosphere of the southern zone, does not hold, for it is broken up into blocks by

the irregular disposition of land and sea. There is a low-pressure area over the North Atlantic Ocean, which extends further east in winter than in summer. Another region of low pressure is found over the North Pacific. The two corresponding high-pressure areas are over North America and Siberia in winter, but in summer the chief of these lies between Greenland and Norway. The shifting of these areas greatly interferes with the regularity of the winds, yet the influence of the east-south-east winds flowing from the Eurasian high-pressure area in winter is sufficiently marked to produce a general north-westward drift, as proved by the drifting of the *Fram* ; moreover, Peary complained of frequent and violent gales. There is some evidence also of winds blowing outwards from the pole, as in the southern region, especially during winter and spring.

Fog seems to be fairly general in both zones in summer, especially where open-water spaces occur in the midst of an ice-covered sea. Precipitation is remarkably slight throughout polar regions, and it occurs usually in the form of separate ice-crystals—' diamond dust,' as it has been called. The great extent of snow-covered surface is explained, not by the quantity of snow that falls, but by the slowness of evaporation and the slight amount of melting that can take place at such low temperatures.

Speaking generally, the North Frigid Zone, in spite of its greater climatic variations, seems far more adaptable for life than the southern. During its brief summer the air is clean and dry, with a brisk freshness, the sunshine is brilliant, the sloping land surfaces of the coasts, where exposed to the sunshine, become free from snow, and an abundant flora of the Arctic type springs into life. Then, although the land surfaces are fragmentary mammals of quite large size are found, such as reindeer, bears and foxes[1] on land, seals and whales in the waters.

In the southern zone the summer temperature is considerably lower, fog is more frequent, and thus the climate itself is inhospitable. There is also an extraordinary absence of plant life throughout Antarctica, only two specimens of flowering plants

[1] Two Norwegians who wintered in Spitsbergen in 1919–20 succeeded in trapping about 250 foxes.

having been discovered ; the rest of the flora, which is extremely sparse, consists of nothing higher than mosses and lichens. Although whales and seals are plentiful in the surrounding seas and quantities of birds of few species crowd the coasts, no land mammals whatever have been found and no freshwater fish, so that the whole huge continent is devoid of food for either animals or man. It may be that, with increased facilities of travel, some part of the Arctic regions could become in time a pleasant summer resort, but there is little hope that man will ever really control the dreary wastes of Antarctica.

# SECTION III. THE GEOSPHERE

## XII. The Surface of the Earth

*Distribution of sea and land.* The term 'geosphere' is used to designate the entire surface of the globe, including both land and water. If we could view the Earth from an adjacent planet, such as Mars, we should see it only as a luminous body, its light, like that of the other planets, being almost entirely reflected from the Sun. A nearer view would show the partly cloudy, partly clear, envelope of the atmosphere, enclosing it like a globe of glass and revealing in its depths a surface three-parts water-covered, the remaining part emerging in irregularly distributed masses and constituting the only portion available for the abode of the air-breathing human race. We must, perforce, take a humbler view of man's importance than did the philosophers of old. According to them the Earth, being constructed for man's special use, consisted mainly of land, and their idea of the disposition of sea and land was coloured by the same opinion.

*Ancient views.* The three main features expressed in the ancient views of sea and land distribution are :

1. The surface of the globe was held to be mainly land, the habitable part of it having great length (east and west) as compared with its width (north and south).[1]

2. The most important parts were represented as being in the centre of the land surface and were shown either in the centre of a map or towards the top, i. e. in the east.[2]

3. The arrangement of the various parts was strictly symmetrical, the theory being that, otherwise, they would not balance each other.[3]

[1] See Ptolemy's map, p. 32.

[2] See the Hereford map, p. 18.

[3] See Herodotus, Book IV, p. 36 : 'Thus much, however, is clear : if there are Hyperboreans there must also be Hypernothians' (Rawlinson's translation).

The Earth, being generally considered to be flat and circular, would show its entire face; practically the whole surface of the disc would be occupied by land, the ocean surrounding the whole. The region round the Mediterranean being most familiar, that sea occupied a central position and Delphi, or later Jerusalem, marked the central point on the Earth's surface.

A difficulty arose as to the relative amount of surface that could rightly be apportioned to each continent, seeing that the three continents must be exactly equal in size. After much indecision a quarter of the surface was allotted to each, the remaining quarter being a No-man's land.

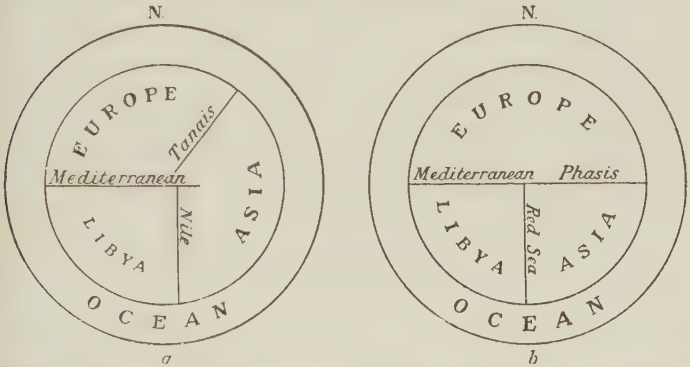



FIG. 39. Diagrammatic representation of the Distribution of Land and Sea, (*a*) according to Hecataeus, and (*b*) according to Herodotus. For the sake of simplicity the north has been put at the top of the map. Hecataeus in his map does not definitely mark off Asia from Libya.

Later, Hecataeus[1] and Herodotus[1] held different and conflicting views on this subject, which may be diagrammatically represented as above (see fig. 39).

Hecataeus, using the Mediterranean, Nile, and Tanais (Don) as the natural boundaries, assigned to Asia practically the whole eastern half of the surface.

Herodotus, taking the Red Sea (parallel to the Nile) and the Mediterranean as boundaries between Europe and Libya, Libya

[1] For actual maps see J. Scott Keltie and O. J. R. Howarth, *History of Geography* (Watts, 1913).

and Asia respectively, assigned to Europe the whole northern section, making the Phasis (Rion) [1] the boundary between Europe and Asia.

The early philosophers believed that the water-divisions of the globe were all connected with one another by means of the surrounding ocean, and Hecataeus, in his map, shows the Nile arising thence.

Herodotus, however, goes further in his demand for symmetry. The Ister (Danube) and the Nile, being on the same meridian, must exactly counterbalance. It being known that the trade-route following the Ister trended westward and, consequently, that the river rose in the west and flowed towards the east before turning south, the Nile must follow the same course. Hence, in his map, the Nile rises just south of the Atlas mountains and has a long eastward course before turning north. Other contentions were that the Caspian—being part of the Northern Sea—counterbalanced the Red Sea—part of the Southern—and that Asia and Libya being circumnavigable, Europe must be so also.

It is important to emphasize these ideas about symmetry because, curiously enough, when, in the Middle Ages, so much really useful knowledge seemed lost, these misleading views of sea and land distribution survived and gave rise to the celebrated wheel maps, which were constructed exactly on this principle. These maps consisted of a T within an O, the O representing the circular Ocean, and the T the Mediterranean Tanais, and Nile. Later these maps were held to satisfy the requirements of Christianity, the centre being transferred from Delphi to Jerusalem.

The oval map of Beatus (730–98) reflects this influence, and the Hereford map (about 1307) shows little improvement.

No better idea of general land and sea distribution was attained until after the translation into Latin of Ptolemy's *Geographia*, which was completed by Angelus in 1410, and from about that time knowledge increased so rapidly that this work

[1] A river running westward into the Black Sea, parallel to and just south of the Caucasus Mountains.

quickly became obsolete. From the fifteenth century till now, one discovery has succeeded another, so that the configuration of the land masses of almost the entire Earth's surface is accurately known.

*Impermanence of outline.* Turning now from a review of the evolution of geographical knowledge on the subject of the surface configuration, we are, unfortunately, obliged to ignore the actual evolution, which has been going on all through geological time, and to consider only the Earth's face as known from the days of early history till now. It must not be forgotten, however, that the present distribution is the development from past forms and is not permanent, although for practical purposes we may consider it so.

*General features of land and sea distribution.* A glance at a terrestrial globe reveals the following facts :[1]

1. The proportions of sea and land surface are very unequal ; there are a little more than 141,000,000 square miles of water and a little less than 56,000,000 square miles of land, or, in other words, water covers about 71½ per cent. or rather more than seven-tenths of the surface.

2. The main land masses are grouped in the northern hemisphere and form an almost unbroken ring round the North Polar Seas. This feature is emphasized when we realize that the North Sea and part of the North Atlantic Ocean are of such slight depth that if the sea-level were to sink 600 feet they would be land.

3. Corresponding to the land-ring on the north we have, outside the Antarctic continent, a water-ring on the south. This sends out water-spurs northward which taper, as do the land-spurs southward, and the two alternate like the interlacing fingers of the two hands.[2]

4. The land masses taper so rapidly that hardly any land stretches more than half-way from the equator to the South

[1] Small hand-globes should be used for these observations such as those supplied by Messrs. Philips.

[2] Placing the two hands north and south over the globe it is seen that the three fingers of the left hand cover land, while those of the right, interlacing with them, cover water.

Pole, so that, not counting the Antarctic continent, the land ends in the southern hemisphere—except for the extreme tip of South America—at a latitude equivalent to that of Rome in the northern, and entirely at a latitude equivalent to that of Edinburgh.

The exact ratio of land to land in the two hemispheres is 2·25 : 1 ; of land to water in the northern hemisphere, 12 : 13 ; and of land to water in the southern hemisphere, 1 : 14·5.

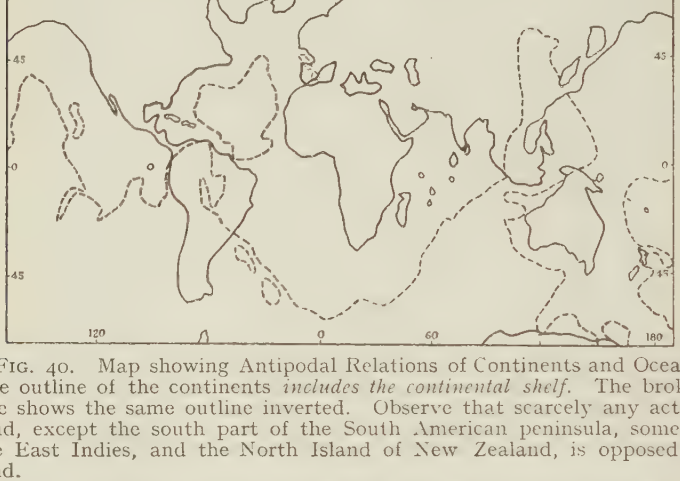



Fig. 40. Map showing Antipodal Relations of Continents and Oceans. The outline of the continents *includes the continental shelf.* The broken line shows the same outline inverted. Observe that scarcely any actual land, except the south part of the South American peninsula, some of the East Indies, and the North Island of New Zealand, is opposed to land.

(Note.—Children much enjoy getting this result for themselves by cutting out the black outline and placing in position the pieces thus produced, using the cut-away portions for the oceans. These can be coloured blue and placed on the others in the reversed position

5. The interlocking of land and water is so arranged that each great land mass has opposed to it, on the other side of the globe, a water mass ; for instance, an imaginary rod piercing through the heart of Africa would emerge in the centre of the Pacific Ocean (see fig. 40).

6.[1] The land which encircles the North Pole falls into three

[1] Nos. 6, 7, and 8 are best studied in a map of the world on any projection with parallel and equidistant meridians.

main divisions, each roughly triangular, with the broad base to the north and consequently the acute angle pointing south. These, which are best seen when the shelf is reckoned as part of the continental mass (as in fig. 40), are :

(i) North and South America ;

(ii) Asia and Australia ;

(iii) Europe and Africa, which, however, taper to the north as well as to the south.

The Antarctic continent is a fourth division, but has its chief extent at right angles to the other three, as will be explained below.

The physical discontinuity of Europe and Asia is now masked, owing to the fact that the great Aralo-Caspian depression, which extends northwards to the western plain of Siberia, is no longer sea-covered, although it is partly swampy and the region around the Caspian is below sea-level (see map of lowlands and continental shelf below, p. 132).

7. A well-marked zone of depression extends right round the Earth, forming midland seas, which roughly separate the land masses into northern and southern parts. This is seen passing between North and South America, between Europe and Africa, where it occupies the Mediterranean trough and is represented also by a depression extending further eastward. It appears again in the Red Sea and Persian Gulf, and then, as part of the Indian Ocean, separates Australia from Asia.

8. Two of the southern continents lie further to the east than the corresponding northern ones. Thus South America is further east than North America, Australia is east of Asia, but Europe and Africa lie almost due north and south, though the peninsular part of Africa is east of north-west Africa and western Europe.

*Symmetrical arrangement.* A careful scrutiny of the globe's surface with these facts in mind leads to the discovery that, with due allowance for irregularity of outline and reckoning as land a few shallow-water areas, land and sea are arranged with a certain rough symmetry. There are, in fact, four main hollows and four elevations antipodal to each of these.

*Practical demonstration.* The easiest way to test this is to

sketch the outlines of the land and water areas on an ordinary compressible india-rubber ball and then to press in the parts which represent the oceans. The outstanding parts will then correspond to the land masses, and in each case the hollow will be found to be roughly confronting a crest on the opposite side of the ball.

The elevations or land masses and hollows or water areas are thus opposed :

| | | |
|---|---|---|
| Elevation | opposed to | Hollow. |
| Europe, Africa, most of Asia | ,, ,, | Pacific Ocean. |
| North America | ,, ,, | Indian Ocean. |
| Australia, a small part of Eastern Asia | ,, ,, | Atlantic Ocean. |

These all run mainly north and south, thus roughly parallel to one another.

Antarctica is opposed to the Arctic Ocean.

The only important land mass that interrupts this symmetry is South America, which is opposed to a small part of Central Asia.

The plan of a collapsed ball accounts therefore for antipodal relations, but in no way explains the central depression nor the lateral shift mentioned above.

*Illustration by tetrahedral theory.* In connexion with these characteristic features, it is interesting to mention once more the tetrahedral theory of W. Lowthian Green. This theory, if it does not rest on sufficient evidence to justify its adoption, as explaining the reason for the present shape of the Earth, is yet unequalled as representing all known facts in a simple and graphic manner. Lowthian Green, as stated above, took the view that a collapsing spheroid tends to become tetrahedral in outline, as shown in the case of the india-rubber ball. Following this up, he showed that the tetrahedral form being attained, not only the relations of land and sea would be accounted for, but also the above-mentioned eastward trend of the southern continents, the median dislocation of the land-masses, and the trilobed shape of the Antarctic continent.

It is not necessary to use for this purpose a six-faced tetrahedron, such as Lowthian Green used for the sake of approximating the form as nearly as possible to that of the Earth, as an ordinary tetrahedron shows the main features well.

For illustrative purposes, a simple tetrahedron may be made in cardboard, using for it the net given in crystallography books, or it can be shaped in plasticene. If cut out in shrinkable material such as potato, it will probably, after shrinking, show the features in an emphasized manner, and this can be reproduced in plasticene on a larger scale. In class, each pupil should,

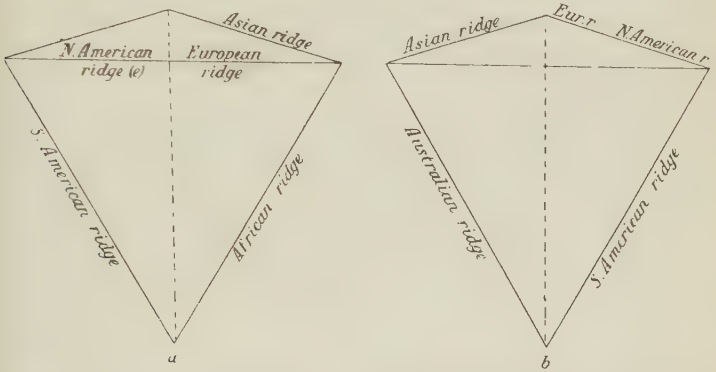



FIG. 41. Drawings to show Tetrahedral Arrangement of Ridges and Faces. (*a*) Atlantic face ; (*b*) Pacific face.

of course, produce his or her own model. It is also important to explain why this figure is chosen, seeing that it is not the Earth's actual shape.

The central line of lateral shift follows naturally on this theory of deformation, owing to the Earth's rotation. If the Earth is collapsing into a tetrahedral shape, there will be slight dilation going on in the northern part and slight contraction towards the south. As a body contracts, its rate of rotation increases and conversely becomes retarded owing to dilation. This may explain the fact that the most southern continents are slewed round towards the east. At the same time, rotation being retarded in the north, a condition of stress will be set up in

the central part. This plane of stress and torsion is believed to show more markedly in some continents than in others and is lost in passing through the oceans.

According to Lowthian Green, this plane forms the deep Mediterranean trough and Persian Gulf; then, crossing the Indian Ocean, it passes close to the south Asian coast until it reaches the Pacific. Crossing the Pacific, it divides North and South America and finally joins the Mediterranean again on the further side of the Atlantic.

Another feature, most clearly illustrated by this method, is the trigonal form of the Antarctic continent, which projects towards each southern land-mass and is believed to be really a continuation of the ridge in each case (see map of Antarctic regions below, p. 145).

Further dignity accrued to this theory through the work of Michel-Lévy,[1] who supported it by geological evidence and showed that the known principal folds of the Earth's crust might in this way have formed outstanding ridges or lines of weakness; moreover, that along these lines the chief volcanic and seismic manifestations occur. It seems, in any case, not impossible to suppose that the contraction which took place in the cooling Earth caused it to take to some extent a four-sided form, if not that of an actual tetrahedron.[2] Water, collecting in the sucked-in hollows of the flattened faces, would leave the intervening ridges as land. This would give the antipodal arrangement, and the concentration of land towards the north would be helped by differential rotation.

Until, however, much more is known about land and sea distribution in the geological past, this simple conception should be considered as a useful way of summarizing present facts, rather than as an explanation of them.

*Dynamic theory.* As mentioned above under 'The Shape of

[1] For a further account of this see below under Lithosphere, p. 184.

[2] W. Lowthian Green points out that tetrahedral collapse actually occurs in nature, in bodies where a spherical crust encloses a fluid interior, as in the case of soap-bubbles, coco-nuts, &c. The same lines of weakness are noticeable in broken glass or ice, the first main cracks forming more or less at an angle of 120° with one another.

the Earth', these special features, shown in the arrangement of land and sea, were used by Professor Love as proofs of his dynamic theory of the Earth's configuration, and this seemed to lead up to something rather similar to the tetrahedral form but along different lines. In his address on this subject to the Mathematical and Physical Section of the British Association Meeting at Leicester in 1907, he based his reasoning on the fact that the Earth's centre of gravity does not coincide with its actual centre, and went on to show the combined effect of this and the Moon's attraction, when it was nearer the Earth, on the rotating planet.

By means of mathematical reasoning, illustrated by a series of very clear diagrams, he accounted thus for the general shape of the Earth and also supplied explanations of the most striking phenomena of land and sea distribution, namely :

1. A tendency for one hemisphere to be elevated and the other depressed ;

2. The existence of a well-marked equatorial region of depression extending round the world ;

3. The antipodal arrangement of continents and oceans ;

4. The skew position of the southern continents in relation to the northern.

Professor Love's paper should be carefully studied, even by those who cannot follow the mathematical deductions, as the diagrams are very suggestive and the whole problem is stated with great lucidity.

# SECTION IV. THE HYDROSPHERE

## XIII. General Description of the Hydrosphere

The term 'Hydrosphere' is used to distinguish the aqueous portions of the globe from the 'Lithosphere' or solid part and the 'Atmosphere' or gaseous part. It includes therefore the waters oceanic and other, but by far the greater part of it is represented by the ocean. The word 'ocean' is Greek in origin, and it may be connected with a Sanskrit word meaning 'all-encompassing', for, before the time of Pythagoras and his disciples, it was believed that the Earth occupied a central position on a round disc and was encircled by the ocean.

*Historical.* The study of the ocean formed an important part of ancient as well as modern research. Aristotle and Pliny both had formed definite ideas about it, and an account of it constitutes the more scientific part of the *Geographia generalis* of Varenius. As early as the seventeenth century, special work was being done in this direction. The experiments of Marsigli in the Mediterranean were followed up by the great eighteenth-century voyages of circumnavigation, and the nineteenth century was marked by the world-wide development of the trade routes. In December 1872 the *Challenger* was sent out on a special exploring expedition to the Atlantic, with the ostensible aim of preparing the way for the establishment of further telegraphic communication between England and America. Similarly in 1874 the *Tuscarora* was sent out to the Pacific. The work of the *Challenger* was supplemented by the *Gazelle* in 1875, and splendid work has since been accomplished on board the German ship *Valdivia* in 1898. The results of Nansen's exploration of the Arctic Ocean in the *Fram* were published in 1894, and several well-known Antarctic expeditions have been made in recent years, greatly adding to our knowledge of the Southern Ocean. The Atlantic Ocean is the part that is best known, having been

nost frequently explored. The *Atlas Oceanographica* of the Deutsche Seewarte' is a most valuable contribution towards ur knowledge of both Pacific and Indian Oceans.

Oceanography is a modern science and comprises :

1. The study of the form of the sea-floor ;
2. Knowledge of the nature of the sediments there deposited ;
3. Examination of the chemical composition of the water ;
4. Knowledge of its physical condition, including density, temperature, colour, &c. ;
5. Acquaintance with its movements ;
6. Study of the fauna and flora.

*The ocean as a whole.* The form of the ocean as a whole, and f the basins of which it consists, is the first and most important f these.

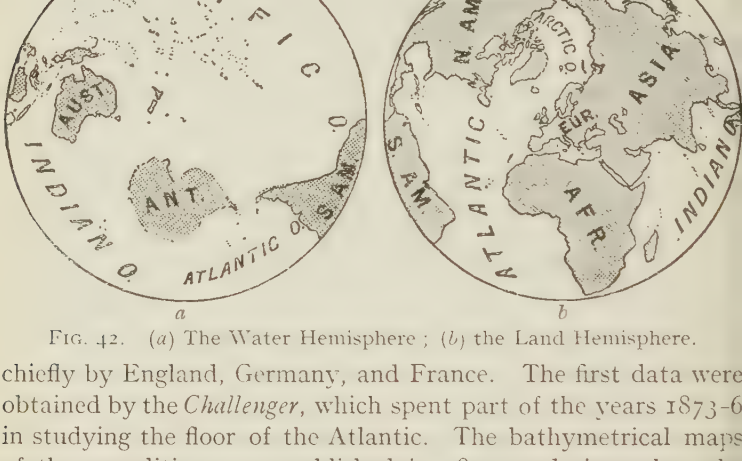
The ocean as a whole is a continuous mass of water permanently overing seven-tenths of the Earth's surface and varying con-iderably in depth in different parts, the average depth being bout two miles. A knowledge of the ocean's extent is confined o modern times, for, until late in the Middle Ages, it was ssumed that the amount of the land on the Earth's surface ar exceeded that of the ocean. Abel Tasman's (1642) voyage viped out of existence the Great South Land, the name given to he hypothetical southern continent, and Captain Cook (1768–71) urther proved beyond doubt that any land existing in that region nust be confined within the Antarctic Circle. From that time on-vard a somewhat clearer notion of the relative extent of land and vater on the globe obtained. The part of the present work which lealt with 'Distribution of Land and Sea', Ch. XII, showed us hat there is, roughly, a land and a water hemisphere, the centre of he land hemisphere being near the mouth of the Loire and that of he water hemisphere antipodal to it, in the South Pacific Ocean.

The great sheet of water considered as a whole is quite irregular n shape, as it fills all the hollows of the globe that are below certain level, except for a few land-locked areas. Its surface, eing practically horizontal, affords a useful datum level [1] from

[1] Sea-level on English maps is the estimated mean level of the sea at iverpool, which is 0·650 of a foot below the general mean level of the sea.

which the heights of the land and the depths of the ocean are measured. The irregularity of its shape is due to intervening masses of land and, although the surface waters are continuous, each partially land-barred area has characters of its own so individual, that it is usual to treat the whole as five separate oceans instead of as one.

*Form of the ocean-floor.* The form of the ocean-floor has been gradually made out by means of soundings, which have been taken in the course of a series of scientific expeditions sent out




*a* *b*

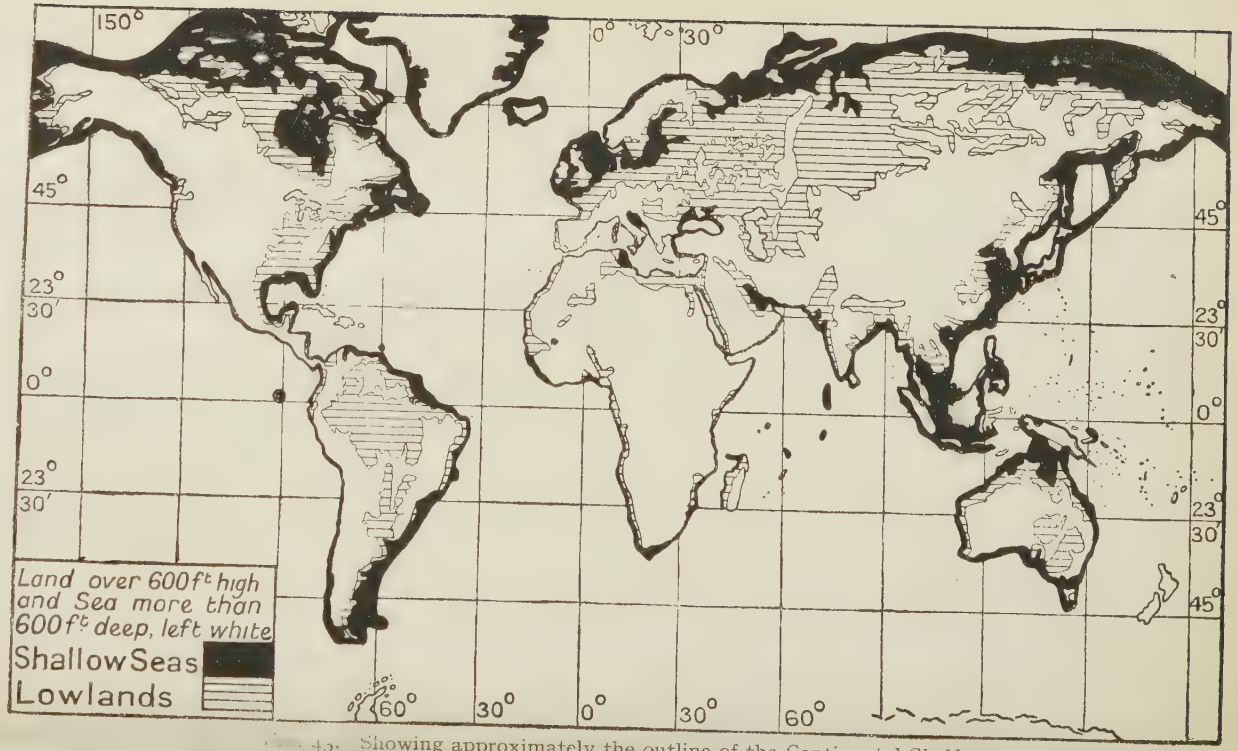
FIG. 42. (*a*) The Water Hemisphere; (*b*) the Land Hemisphere.

chiefly by England, Germany, and France. The first data were obtained by the *Challenger*, which spent part of the years 1873-6 in studying the floor of the Atlantic. The bathymetrical maps of the expedition were published in 1895, and since then the Admiralty charts have reached a high pitch of exactitude. It was soon discovered that the contours of the ocean-floor were not quite what might have been expected. Instead of sloping gradually downwards from the sides and attaining its greatest depth towards the centre, the floor was found to be undulating, consisting of ups and downs somewhat like the surface of the land but much less accentuated. Moreover, there was no uniform slope from the continental shores outwards; instead of this a well-marked shelf or platform, like the rim of a pie-dish, forms a submerged extension of each continental shore-line. This

appears to be part of the original continental mass, which has been sunk comparatively recently, for it shows in places characteristic land-forms, such as old river valleys. Another view, however, is that the shelf has been built up by material carried down from the land, its border marking the limits reached by such deposits. This continental shelf slopes gently down to a depth generally of about 100 fathoms, and then its seaward edge plunges steeply to the greatest oceanic depths, sloping up thence again to the general level of the ocean-floor. As a matter of fact, most of the 'deeps' are found, not in the central parts of the ocean away from land, but in the regions just beyond the continental shelf. This is very characteristically seen in a bathymetrical map of the Pacific, where the great deeps all cling to the edge of the vast oceanic platform which links Asia with Australia and the island groups of Micronesia and Melanesia (see fig. 45, p. 138).

Speaking generally, rather more than half the ocean exceeds a depth of two miles.

Besides the continental shelf, the sea-floor has one other very characteristic feature, namely, the convexity of its curves. If only the water could be drained away, leaving the sea-floor bare, and we had a power of vision that would allow us to grasp sufficiently large areas, our eyes, long trained and accustomed to the concave curve which nearly everywhere marks the effects of denuding agents on the surface of the land, would be at once arrested by the peculiarity of this feature. The probable explanation of these curves is that they are the original wrinkles formed in the crust by the shrinking of the Earth's interior, undefaced by the work of time. The uniformity of these curves must give a great monotony to submarine scenery, justifying Rudyard Kipling's description of 'the great, grey, level plains of ooze', although, as the charts show, a dead level is rare, the whole being rather gently undulating. Lately an enterprising photographer has obtained a few submarine photographs off the West Indies, but these, while showing the abundance of plant life, give no general views; further developments in this direction would, however, be of great interest and an assistance to other methods.




Showing approximately the outline of the Continental Shelf

The four main characteristic features of the ocean-floor, namely :

1. the undulatory character of the surface ;
2. the presence of the continental platform ;
3. the comparatively sudden and sharp descent to great depths outside the platform, with a gentle upward slope to the general level beyond ;
4. the convex nature of the curves ;

are well seen in the following section (fig. 44).

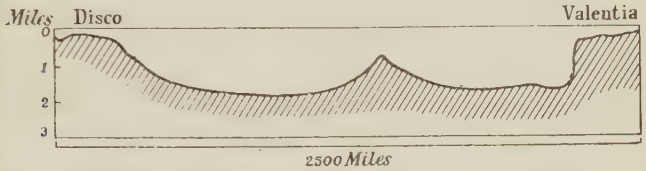



Fig. 44. Section across Atlantic Ocean with vertical scale greatly exaggerated to show (1) continental platform ; (2) sudden descent to great depths outside the platform ; (3) general undulatory character of surface ; (4) convex curves. (After de Lapparent.)

*The nature of the sea-floor.* The nature of the material constituting the sea-floor in the neighbourhood of land differs entirely from that in mid-ocean. The continental shelf consists of sands and gravels of the same nature as those which form land, and often retains part of its land-configuration. On the continental slopes beyond the 100 fathom line, fine-grained materials such as blue, green, and red muds prevail—the colour being due mainly to ferruginous matter—together with volcanic and coral muds in the neighbourhood of islands. Away from the continents, the land-derived material becomes more and more rare and, about 200 miles from the coast or occasionally much less, mechanically formed muds have yielded insensibly to definitely pelagic deposits. These consist of the shells and skeletons of marine organisms, which flourish in such quantities that their fragments must be falling in a continuous shower upon the bottom. Thus deposits consisting mainly of carbonate of lime or silica are built up, mingled with water-logged pumice and the débris from submarine volcanoes. The fine greyish material

thus produced is something like putty powder in consistency and is called ' ooze '. When built of Radiolaria or Diatoms it is mainly siliceous, but consists of carbonate of lime when formed of the tests or ' shells ' of Foraminifera. Where these oozes fail, that is, in the extreme depths, their place is taken by the red clay, which seems to be formed in the main of disintegrated volcanic material. This exists, doubtless, in considerable quantities elsewhere, but its presence is masked by the preponderance of other deposits already mentioned.

To summarize, the ocean-floor is composed of deposits which are :

1. terrigenous or land-derived ;
2. pelagic or ocean-derived.

The terrigenous deposits vary in texture according to the distance from land but, in substance, are derived from it. They are : shingle, gravel, sand, calcareous material (shells, corals, &c.), or, in deeper water, clay and mud.

The pelagic deposits are built of the remains of sea-organisms and are classified according to the preponderating organism. In the greatest depths, the red clay is almost free from the remains of organisms, being, in the main, volcanic.

*Chemical composition of sea-water.* The water of the ocean differs from pure water in containing a large quantity of mineral matter in solution, as much as 3 per cent. of its weight consisting of mineral salts. By far the most important of these, as regards quantity, is common salt, which gives the water its characteristic taste. In some parts of the world this salt is extracted by evaporation and utilized in commerce. Carbonate of lime is also present, but is used up in part by the countless inmates of the sea, which build their bony framework or compose their shells of it. The amount of mineral matter in the sea receives large and continual contributions from the rivers, some also having been, doubtless, present in the original hollows where the water first collected. The minerals in solution can be separated out by evaporating a little sea-water in a tin lid or a porcelain dish. The proportion of mineral matter present can thus be seen, and further experiments as to ' hardness ' should

be made by shaking a given quantity of water with a measured amount of soap solution.[1]

*Physical properties of sea-water. Density.* The presence of so much solid matter in solution gives sea-water a higher density than fresh water, hence the greater buoyancy of objects floating in sea-water and the comparative ease of swimming in the sea.

*Temperature.* The temperature of the ocean varies both horizontally and vertically. The temperature of the various parts at different depths has been calculated by means of deep-sea thermometers, from the electric resistance of telegraph cables resting on the ocean-floor, and from the temperature of large masses of mud and ooze. The heat of the sun greatly affects the upper layers, so that near the equator the temperature on the surface may be as much as 80° F., whereas near the poles the surface water is near freezing-point.[2] The cool water of polar regions tends to sink below the warmer layers and consequently spreads slowly over the ocean-floor into equatorial regions. It carries with it some of the gases of the atmosphere into the abysmal parts of the ocean and thus provides the deep-sea creatures with the means of respiration.

About 100 fathoms down, seasonal variations are sometimes reversed, as discovered in the *Michael Sars* expedition, while at about 150 fathoms they practically disappear[3] and the temperature is low but constant. Generally speaking the temperature of the water decreases from the surface downwards, but the rate of this varies greatly at different depths. In various parts of the Atlantic it was found that for about the first 50 fathoms the fall was rapid. Beyond that it changed slowly, then again rapidly, then very slowly till the bottom was reached, where, at great depths, the temperature is only a little above the freezing-point of fresh water.

*Colour.* The colour of the ocean is perfectly definite, but must not be judged by the varying tints due to the reflection from

[1] See any book on ' General Elementary Science '.

[2] The freezing-point of salt water varies according to the amount of salt, but it is always a little lower than that of fresh water.

[3] See *The Depths of the Ocean*, by Sir John Murray and Dr. Johan Hjort, p. 288 et seqq.

the sky. Painters know that every surface, however small, exposed to the sky, reflects something of its blue colour, but most people only realize this fact when they see a large surface reflecting it, as in the case of the sea or a lake. Poets of all time have revelled in this wondrous, varying stretch of colour, and have described it as of every shade, including even black and white. This, however, is not the colour of the ocean itself, which can only be seen when the reflection from the sky is shut out. On a calm bright day, the shadow cast by the ship often reveals the sea's true colour to the seafarer, or still better is it to sink in the water a tube blackened inside. The colour seen inside the tube can be compared with a scale of colours, devised by Forel, and in this way the colour of the ocean has been charted over wide areas. The application of Byron's well-known apostrophe, 'Thou deep and dark blue ocean', is only truly justified in certain large areas remote from land, where the deepest and clearest ultramarine blue certainly obtains. This graduates, through various less pure shades of blue, to more and more yellowish tints nearer the shore-lines, so that, as viewed from the coasts of the continents, the colour is distinctly greenish. The only land-locked portion showing the deep blue colour is the central part of the Mediterranean Sea. It has long been supposed that the deeper blue colour was due to a high temperature and greater degree of salinity, but recent observations have proved that this is not the case. The colour depends apparently on the presence or absence of material in suspension, the water being deepest blue where it is most transparent, free, that is, from mechanical sediment of all kinds. The nature of the substances in suspension, whether plant, animal, or mineral particles, is immaterial as affecting the colour. Nearly all of these produce a greenish effect, which is therefore always present near the shore-line, as also in the deeper parts where there is much plankton, i. e. surface life.

## XIV. The Physical Divisions of the Hydrosphere

*The ocean units.* The interruptions caused by land and the development of the continental platforms in some places enable us to divide the hydrosphere into certain definite parts, these being called oceans. Each of these great oceans is, as it were, a morphological unit. Its shores are formed by otherwise distinct and generally rather widely separated continental masses, but into these it infuses, one might almost say, its own personality, so as to weld them together with it into an organic whole. These land masses are continued on most sides beneath the ocean into a well-defined submerged continental shelf, which occupies about 10 15 per cent. of the ocean-floor. The communication of one ocean with another is usually widely open and each is often bordered by seas, which have characters more or less divergent from it. The Pacific, Atlantic, and Indian Oceans are typical and lie in three clearly individualized basins, open widely to the south and ending more or less blindly northward. The Arctic Ocean is more of the nature of a border-sea than an ocean, as it really forms a kind of gulf of the North Atlantic, being organically connected with it. The so-called Antarctic or Southern Ocean is, at present, not very clearly defined and may not, scientifically speaking, have an individual existence at all.

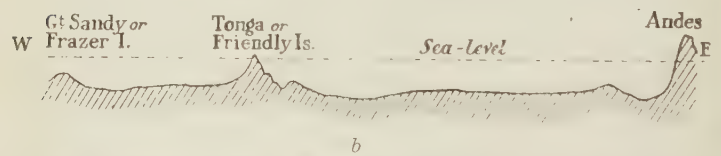
A brief description of each ocean will suffice to bring out its main characteristics and will also show that, if we could only begin studying geography again from the beginning in a truly scientific manner, we should regard the earth's surface as consisting of ocean basins, each basin, with its surrounding land, being subject to the same general laws.

*The Pacific Ocean.* The Pacific Ocean is a huge stretch of water comprising, with the adjacent part of the Southern Ocean, 75,000,000 sq. miles, or more than one-third of the water-surface of the earth. It is somewhat elliptical in form, completely land-locked on the north, except for the narrow Bering Strait, and broadly open southward to the Southern Ocean. If we consider the actual curve of the earth's surface we must imagine

that, in the main, the Pacific floor is gently convex; we know that the continental platforms, broad on the west side and narrow on the east, are separated from this general convexity by marginal grooves in which are situated the great deeps. It may

*a*

Ch, Challenor Trench; M, Miller Deep; T, Tonga Trench; B, Belknap Deep; H, Hilgard Deep; K, Kermadoc Trench.




*b*

FIG. 45. (*a*) Map of Pacific Ocean showing, as far as possible, the moulding of its floor, including the position of the great Asian-Australian platform with its festooned edges and the great deeps adjacent to it. (*b*) Section across the Pacific Ocean along the 25th parallel of south latitude. Scale of height exaggerated about 100 times. (After de Lapparent.)

be that we have here a major crust fold in process of formation between two earth-waves, the Asiatic side showing the gentle downward slope of the wave, the American the abrupt rise towards the crest of the next, the ocean forming the

intervening trough. This would not be incompatible with the theory of Sir George Darwin, that this vast hollow marks the place where the Moon became separated from the Earth, because this separation must have taken place before either body was quite solid. The complexity seems to increase from east to west. Beginning at the west so as to follow the direction of the supposed wave-movement we see that a vast platform, somewhat deeply submerged, knits together Asia and Australia with the neighbouring islands. Of this platform, the uneven surface shows, in some places, deep hollows, and in many others projects above sea-level in the form of islands. This submerged platform presents certain very characteristic features, being in effect steplike, if we can imagine steps worn least on their outer margins, where they are usually worn most. The result is that there are two sets of island-festoons, an inner and an outer. Each festoon partially encircles a mainland coast and shuts in the somewhat deeper waters of border seas. Thus the inner festoon loops the coast of Asia, enclosing the sea of Japan and the China Sea. The outer festoon is flung widely outside this, and around the north-east Australian coast, enclosing several other deeper water hollows. This outer festoon is of a twofold character : the Melanesian islands within, the Micronesian forming the outer fringe. The surface of the submerged platform is punctuated by many island groups, each set, as it were, in its own little socket, for the shallower water favours the formation of coral and the deposition of volcanic muds. The whole of the platform edge is marked by the fact that it plunges at once into the depths, all the greatest deeps of the Pacific Ocean being found along its outer margin. It is easy to imagine that the outer edge of the platform once formed the Asian-Australian shore-line. We must, however, guard against supposing that the disruption of the coast is of recent origin, even geologically speaking, for we have evidence that the separation of Australia dates far back even in geological time. Eastwards of this platform, the floor slopes up to the general prevailing level of the ocean, which is here, in its central part, uninterrupted but for the small Hawaiian platform in the north and by the cluster which constitutes

Polynesia in the centre. The Polynesian groups form a broken connexion between the great Asian-Australian platform on the west and the wide stretch of the South American platform, the surface of which is crowned by few islands. Sloping down gently beyond this, the wave next rises steeply to its crest in the American continent. Thus does the Pacific Ocean form the corresponding trough to the great wave which constitutes Asia on the one hand and America on the other; moreover, it has the characteristics of a wave-trough, i. e. an abrupt slope and a gentle one. We believe, therefore, the Pacific Ocean to be of vast antiquity and a direct outcome of the folding of the earth's crust.

*The Atlantic Ocean.* The Atlantic Ocean is entirely different in structure from the Pacific. Its shape is that of a spindle, but the spindle is twisted at its centre, parallel to the contours of the two opposite shores, and the most casual glance shows that the lands on the two sides might almost be fitted into each other like the pieces of a puzzle. South America's convexity fits into Africa's concavity; moreover, the heights and lowlands correspond, their direction being at right angles to that of the ocean's greatest length, so that they might pass right across it. The Atlantic then is more of the nature of a great ragged fracture than a fold.

Still more remarkable is the form of the ocean-floor. A well-marked ridge, sunk beneath shallow water, traverses it from north to south, dividing it into two distinct basins, east and west. This is called the ' Dolphin Ridge or Rise ' in the north and is joined by the narrow Connecting Ridge to the Challenger Ridge in the south, the whole ridge having the form of a wide **S**. Again, a transverse ridge covered by water less than 500 fathoms deep separates it from the Arctic Ocean by linking Scotland and Iceland with Greenland. This kind of bridge, connecting Europe and America, is called the Wyville Thomson Ridge between the Shetland and Färoe Islands and is continued as the Färoe-Iceland and Iceland-Greenland ridges. More recently it has been discovered that the western basin near the equator pushes out eastward, ending off in a hollow more than 3,500 fathoms deep.

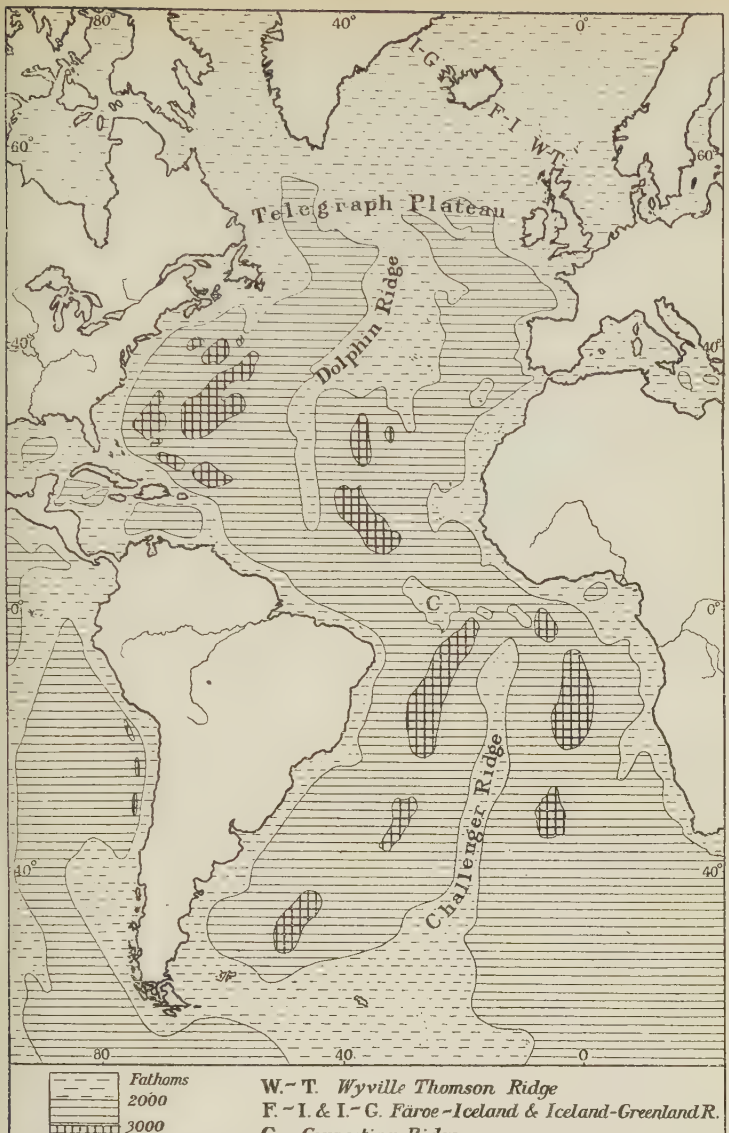



FIG. 46. Map of Atlantic Ocean, showing its division into compartments by means of ridges and the disposition of the islands, either on the ridges or on the continental platforms. Notice that St. Helena rises from the depths. For section of Atlantic see fig. 44, p. 133.

This gives more prominence to the Connecting Ridge, which thus runs nearly east and west between South America and Africa.

Thus the Atlantic Ocean is roughly divided into four compartments: the two northern, both more or less closed towards the north by the Wyville Thomson Ridge, and the two southern, both broadly open southward but separated from the northern by the Connecting Ridge. This fact has a very marked influence on the movements of the ocean and the distribution of temperature. Deep-seated currents passing from the northern hemisphere to the southern are hindered by the transverse crest. The deeper waters of the eastern and western troughs cannot mingle. Warmer waters from the Atlantic can pass over the Wyville Thomson Ridge, but little of the colder water can pass from Arctic regions to the Atlantic. On the south, however, deep-flowing polar water has been traced nearly as far as the equator. Summarizing from these data we obtain the following facts:

1. The Atlantic Ocean is of the nature of a fracture rather than a fold, for the main lines of folding pass across it and its opposite shores fit into one another;
2. Its floor is roughly divided into four compartments by a longitudinal ridge and a nearly central transverse ridge.

The result of this conformation is that the islands fall readily into groups:

(*a*) Those on the continental platform on either side, really forming part of the original continent;

(*b*) Those on the central ridge;

(*c*) Those which arise quite sporadically from the ocean depth and are, consequently, true oceanic islands. These are very few; St. Helena, one of them, is really the crater of a submarine volcano.

The floor of the Atlantic has been studied more thoroughly than that of any other ocean, as it was easier of access and of more importance commercially; consequently its nature, almost everywhere, is well known. The commonest form of Atlantic ooze is largely made up of *Globigerina* shells—that animal being a minute Foraminifer, which builds shells of calcareous material,

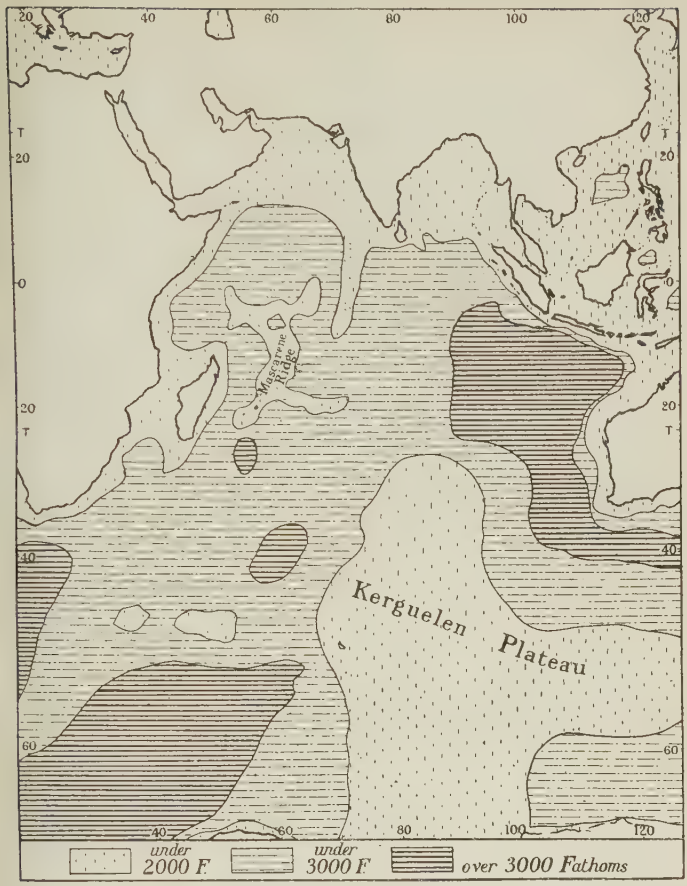



FIG. 47. Map of Indian Ocean showing the memberment of Asia with ustralia and the East Indies by means of a comparatively shallow- ater platform, also the disposition of the islands either on this continental latform or on submarine ridges or plateaux. (Made from soundings aken by Valdivia expedition.)

erforated by tiny strands of gelatinous body-substance. The ame form occurs frequently in the Chalk.

*The Indian Ocean.* The Indian Ocean, unlike the others, is ractically confined to warmer regions. In its northern part it

forms a continuation of the great horizontal median depression of the globe that has in the Mediterranean trough its most characteristic development, and, moreover, the ocean itself shows some striking resemblances to Mediterranean contours. Like that sea it has, on the north, three peninsulas. Of these, the plateau of Arabia on the west is comparable to Spain ; India, the central one, more tapering, and with an island to the south, corresponds to Italy ; while the Malay Peninsula and islands can be compared to the peninsula of Greece with its adjacent islands. Like Italy, India is continuous with a submarine platform, the shallowest part of the ocean basin forming a kind of bridge connecting the peninsula with the islands and Madagascar. Further comparisons can be drawn between the Persian and Cutch Gulfs and those of Lyons and Genoa ; the Bay of Bengal and the Adriatic. Again, as in the Mediterranean, high mountains run east and west in similar positions ; compare the Alps and Himalayas. Large rivers also run parallel to these in each case, as the Po and Ganges, both fed by small but numerous mountain streams on the north. Finally, the Indian Ocean ends bluntly in Australia, as does the Mediterranean in the Levant. The main feature which distinguishes the Indian Ocean from the Mediterranean, i. e. its semicircular form widely open southward, renders it comparable to the Pacific Ocean, which it certainly resembles in miniature as far as shape is concerned. It contains a fair number of islands and its deeps run north and south, being somewhat similar in trend to the rift valleys of Africa. The Indian Ocean being, as it is, the only ocean which, besides being to a great extent land-encircled, is confined to the warmer regions of the globe, has one feature peculiarly its own. This is that the difference in specific heat of sea and land is here manifested in a remarkable degree, so much so that, at the different seasons of the year, a great wind-draught sets alternately from sea to land, and from land to sea, resembling the land and sea breezes described above on a gigantic scale. This wind, called the monsoon, or season-wind, carries the surface water in the same direction, a definite proof that in this case, at any rate, surface currents are mainly due to the set of the winds. Nowhere

the mutual influence of land and sea so clearly seen as in the ndian Ocean, and nowhere else have the atmospheric conditions uch far-reaching effects, seeing that the very existence of vast illions of mankind is directly affected by the regular alternation

FIG. 48. Map of so-called Southern Ocean, showing relations between he outward-extending arms of Antarctica and the southern extensions f the three main continental masses. Note that in this way the separate asins of the three great oceans are partially outlined. (Partly based on nap by W. S. Bruce.)

f wet and dry, warm and cool layers of air, in the regions sur- ounding the Indian Ocean.

*The Southern Ocean* (not really an ocean unit). The Southern Ocean, which appears of such vast extent on the maps, is probably

rather a union of the broad bases of the three great oceans th an organic unit in itself. It is believed by explorers that t Antarctic Continent—about as large as Europe and Austra combined—occupies most of the surface within the Antarc Circle ; it certainly protrudes outside it in places roughly opposi the main continents, and these salient points are connected wi one another by shallow water. What was called the Southe Ocean shrinks then to a ring encircling this land, and what known of its floor, by means of soundings, tends to strengthe the view that the three main ocean basins continue right in it and divide it up, each claiming a share. The *Scotia* soun ings indicate the presence of a rise—or shallow water ridge- from Madagascar to Graham's Land and from there to Sou America, thus outlining the Atlantic Basin. Again, a coast eastern Pacific character is recognized on the west side of Graham Land and one of western Pacific character in Victoria Land lastly, the east coast of Victoria Land is found to correspond wit the east coast of Australia, both being of plateau type, wi mountain ranges parallel to the coast. It appears, therefor as if further exploration may blot out the existence of a definit Southern or Antarctic Ocean from our maps and show the thre great oceans extending southwards until they meet around th shores of Antarctica.

The Arctic Ocean, to be fully understood, should be studied i conjunction with the seas, for Nansen has shown that it is hardl more than a sort of large gulf of the Atlantic and may b classed as a border sea, i. e. a sea bordering an ocean. To und stand this definition we must next examine the distinguishi features of seas.

*The seas.* A sea is a stretch of water more or less separat off from oceanic conditions ; it always has special features its own and differs in several ways, as in salinity and, cons quently, density, from the open ocean. It has special currents its tides are irregular or it may be tideless. It often has a faun peculiarly its own.

Seas are of two kinds : border seas and continental sea The border seas are usually found between the main ocean an

ne land; their surface waters communicate freely with those f the ocean, but their depths do not, being separated off by a ridge n the ocean floor. The existence of this ridge has a marked ffect on the temperature, for in many cases, as in the border eas of the Pacific and Atlantic, e. g. Japan Sea, North Sea, &c., ne sea retains to the bottom the temperature of the water nat can pass into it from the ocean over the ridge. The surface emperature of the water in a border sea often shows very great uctuations; thus the North Sea, where furthest from the ocean, as a surface temperature of 40° F. in winter and 60° in summer.

*The North Sea.* The North Sea, the largest border sea of the tlantic, has an important individuality as forming the direct ighway between the British Isles and the mainland of Europe. n geological times, however, it hardly existed as a sea at all, or it constitutes really part of the continental platform of urope, and as recently as the Ice Age, when we find the first races of human occupation, it actually formed land. The only eep-water part of the North Sea is the Norwegian Gut, which a narrow tongue of the Atlantic licking round the Norwegian oast as far as Christiania Fiord. The map shows at once that l the floor, south of a line extending from the Yorkshire coast o Jutland, has a depth of less than 30 fathoms, and near this ne is the edge of the Dogger Bank, the famous North Sea fishing-round. It was this shallow southern portion of the North Sea hich formed the huge river delta of late Pliocene times. This reat delta disappeared under the accumulations of material piled ver it during the glacial and interglacial periods of the Ice Age, hen the whole North Sea region and the adjacent lands were ore than once covered by the ice-sheets which extended over orthern Europe. During the interglacial period both animals nd man seem to have wandered freely across to our islands from urope, and many species of land-animals, including the mam-oth, left their bones on the Dogger Bank, whence they have been redged by trawlers. Early searchers found also quantities of noor log', or masses of peat, proving the existence of a great bmerged plain, at one time forest, then fen, but now a shallow-ater feeding-ground for innumerable fish. As the ice gradually

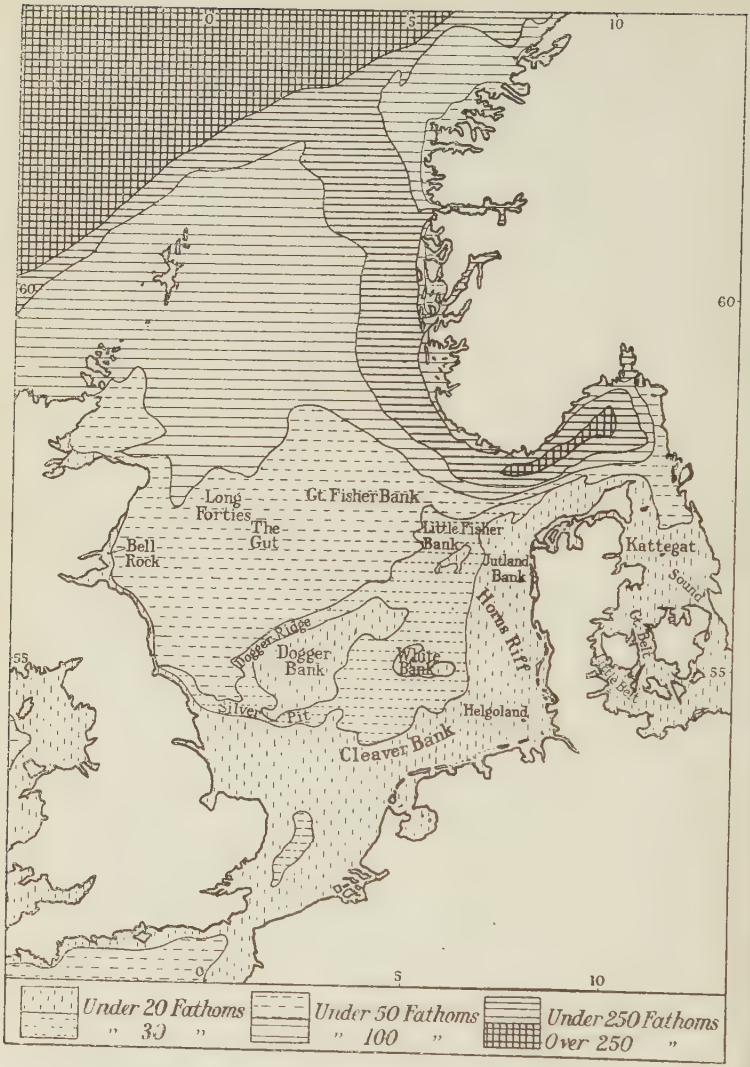



FIG. 49. Map of North Sea, showing the deep Norwegian Gut and the silted-up region to the south.

withdrew the whole region became submerged, as shown by the remains of the large forests still traceable along the coasts below present sea-level. The wide temperature range of the North Sea's surface induces a climate which is continental rather than marine. This sea, being widely open to the north, is much exposed to north and east winds, the latter sweeping over from the frozen plains of northern Europe and Asia. The tides are peculiar, being greatly affected by land interference. The tidal wave enters from two opposite directions. Sweeping up the Channel and through the Straits of Dover, one set of waves visits the shores of the Netherlands and Denmark; the other set enters from the Atlantic on the north and washes the eastern coasts of Britain. The result of the waves meeting is to cause a silting up of the floor by vast quantities of sediment, thus adding to the Dogger and Jutland Banks and helping to form the picturesque dune-coasts of Holland and Denmark.

*The Arctic Sea, usually called the Arctic Ocean.* Under this heading we may also consider the Arctic Ocean, as it combines most of the features of a border sea with some of a continental sea. The Arctic Ocean, so called, is almost completely land-surrounded, and therefore approaches the continental type, but its communication is broadest with the Atlantic, and it is to the Atlantic basin that it must be considered to belong. Though apparently in broadly open communication with that ocean, it is really cut off by a well-marked submarine ridge, the Wyville Thomson Ridge, extending from Norway and Scotland to the Färoe Isles, and thence, under the names of Färoe-Iceland and Iceland-Greenland Ridges, on to Iceland, Greenland, and North America. Another much lower and less-defined ridge, uniting Norway and Spitsbergen with Greenland, divides the Arctic Ocean into two basins, the Arctic Sea proper and the Norwegian or Greenland Sea, the depths of each basin being much greater than was supposed before the time of Nansen. Thus two barriers intervene between most of the deepest polar waters and the Atlantic.

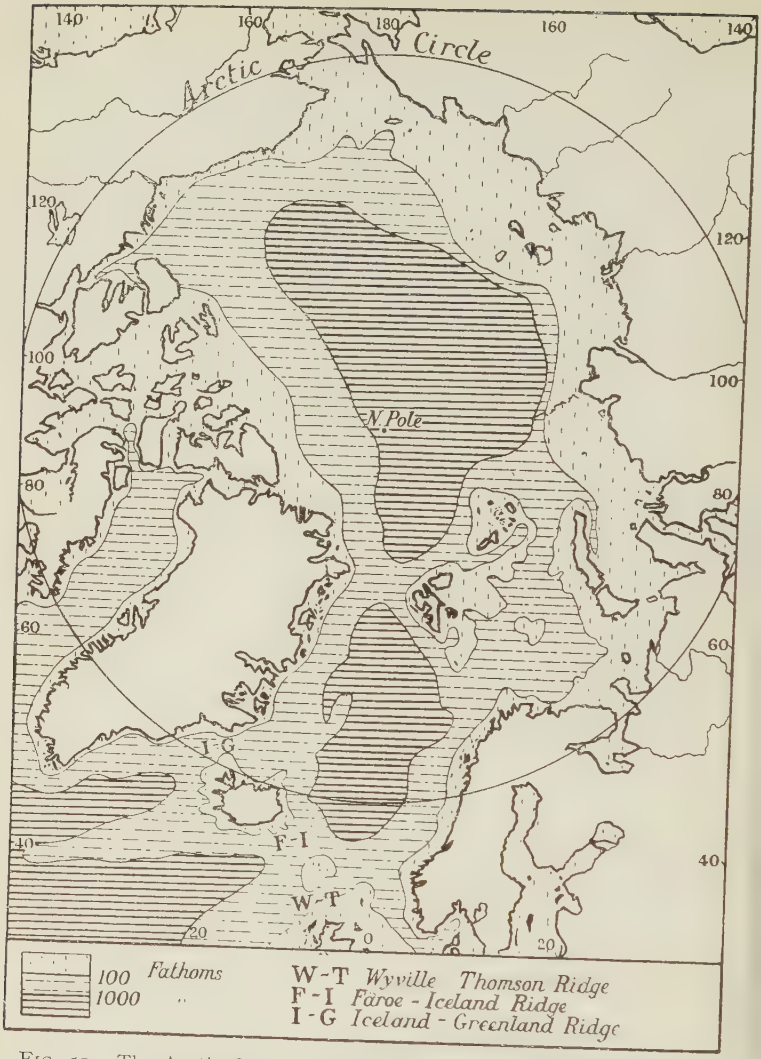



FIG. 50. The Arctic Ocean or, more correctly, the Arctic Sea, showing the two basins, that of the Arctic Sea proper and that of the Norwegian Sea. A submarine ridge extends between these two basins, and another shallower ridge separates the Norwegian Sea from the Atlantic Ocean. Scale of depths as for Mediterranean Sea. (Partly after Nansen.)

The conditions of saltness and temperature are quite peculiar. The surface waters are only slightly salt, owing to the presence of melting ice and the number of rivers which discharge their waters into the basin. Below this cold surface layer, which extends downwards for about 125 fathoms, are found the warmer but very dense waters of the great Atlantic Drift, which, having crossed the Wyville Thomson Ridge, are carried downwards, owing to their saltness and consequent density. Lower down still the water is cold, but of a temperature comparatively high for the latitude; these waters practically stagnate in the depths, as they are unable to pass over the ridge, and therefore can take no part in the general circulatory movement of the ocean. The peculiar character, then, of the circulation and thermal conditions, as also the strong influence of the surrounding land, render this basin almost a continental sea.

*Continental seas.* Continental seas are usually surrounded on all sides by land and communicate with the ocean only by means of quite narrow straits. Their tides are independent of ocean tides and are often hardly appreciable. The absence of tides has a definite effect on the coast-line; irregularities tend to be obliterated, estuaries are filled up or converted into deltas, gulfs and bays become shallow, and the general evolution of shore-lines is in the direction of uniformity. The circulation of these seas is characteristic; strong currents passing through the straits keep up communication with the ocean, but the sea's depths are unaffected by these and the water tends towards stagnation. The temperature of such seas and their salinity are generally quite different from those of the neighbouring ocean.

*The Mediterranean Sea.* The Mediterranean Sea is a typical sea of this kind, as it communicates with the open ocean only by the Straits of Gibraltar, about 600 ft. deep. The formation of this sea is extremely complex, but, speaking generally, it is divided by a ridge near Sicily into two basins, east and west, both of considerable depth. In addition, a series of peninsulas on the

north and of islands mark it off into three seas : the Tyrrhenian, the Adriatic, and the Aegean ; thus any general circulation of the waters is greatly impeded. The margins of the Mediterranean are characterized, except on the south-east, by the existence of high mountains close to and often nearly parallel with the shore ; these are unfavourable to the formation of large river-basins, and consequently the supply of water from rivers is restricted. Towards the east and south, where the climate is almost sub-desert, the concentration of the water increases, so the Mediterranean has to draw on the neighbouring seas. Even then evaporation

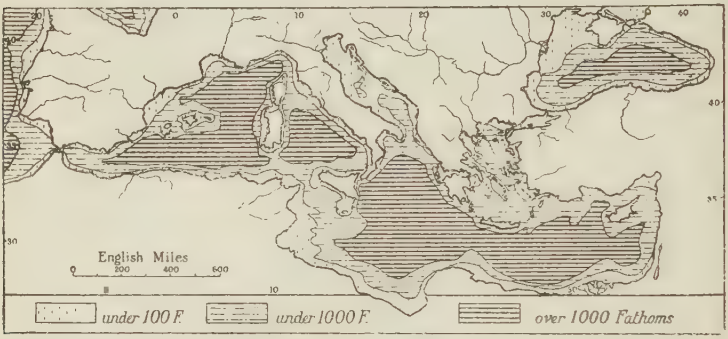



Fig. 51. The Mediterranean Sea, showing submerged ridges separating the basins. These ridges probably formed at some period land-bridges.

remains excessive, and consequently the surface current through the Straits of Gibraltar sets inwards from the Atlantic. The isolation of the sea is shown by its high prevailing temperature, which in summer is almost equal to that of the air. The temperature of the water in the basin cannot fall below that of the water flowing over the ridge from the Atlantic, the temperature of which is relatively high, and thus a supply of warmth above the normal is stored up within this area.

*The Baltic Sea.* The Baltic Sea, also continental, presents another extreme type. It communicates with the Atlantic Ocean only indirectly by means of the North Sea, and with this is connected only by a series of straits. It is almost closed

round by comparatively cold lands, low-lying, abounding in lakes and large river basins, which supply quantities of fresh

FIG. 52. The Baltic Sea, showing its extension north and south, and the shallowness of its basin.

water. The surface waters of the sea are, therefore, distinctly lacking in salt and comparatively cold. The salter water, passing in through the Kattegat, is dense and loses itself quickly in the depths, so that the deeper layers are relatively warm.

The Mediterranean and Baltic Seas present a striking contrast, which may be tabulated thus :

| *Mediterranean* | *Baltic* |
|---|---|
| 1. Extends east and west ; | 1. Extends north and south ; |
| 2. Surrounded by high land ; | 2. Surrounded by low land ; |
| 3. Few large river basins ; | 3. Many large river basins ; |
| 4. Climate almost desert towards east and south ;[1] | 4. Great rainfall ; |
| 5. Temperature high ; | 5. Temperature low ; |
| 6. Water very salt ; | 6. Water comparatively fresh ; |
| 7. Tends to evaporate and draw outside waters in, so current sets inwards. | 7. Tends to fill and flow outwards, so current sets mainly outwards. |

Each of these seas developed its own individual culture at an early period, influencing in a marked degree the history of the world (see below under ' Biosphere ').

## XV. Movements of the Ocean

*Movements of the ocean.* The ocean is never really still ; on the calmest day a general heaving of the surface usually marks the dying out of some storm ; moreover its movements are not confined to the surface, although only the superficial changes are readily observable. Movements discernible upon the surface are usually classified as waves, currents and tides, but only the first of these is confined to the surface, the others forming part of important and deep-seated processes.

*Waves.* Waves are a surface movement of the water only and have the appearance of onward movement in a certain definite direction. To the watcher on the coast, they seem to advance forward in never-ending succession, and in the Atlantic they have the name of ' rollers ' owing to the extreme regularity and evenness of their advance. In fact, however, the apparent onward movement of the wave is illusory, as a cork thrown into the water readily shows. The cork, obeying the direction of the water particles, bobs upwards and downwards, but remains

[1] This does not apply to the basin as a whole as part of the Adriatic coast has the highest known rainfall in Europe.

practically in the same place. The apparent onward movement is similar to that produced by the wind in a field of corn. Owing to the friction of the wind on the surface, each particle of water moves forward on the crest of the wave, vertically upwards in front of it, backwards in the trough and downwards behind it, thus actually describing a small upright circle.

Of these four movements the forward one only is appreciable on the surface.

Close to land, different conditions, however, obtain, for there the friction of the sloping shore acts as a deterrent on the lower part and consequently the upper part, advancing more quickly, topples over and forms a breaker. The soothing rhythm of the advancing wave was thus described by Amy Levy : ' The long slow waves caress the shore.'

Fig. 53. Orbital Movement of Waves. The arrows show direction of movement at the surface. (After E. de Martonne.)

Children often ask why, if waves are caused by wind and the wind does not always blow inshore, yet the waves always seem to march towards them up the beach. This is due to the slope of the shore ; the wave may be approaching it diagonally, but in that case the end of the wave nearer the sea's edge is retarded more by friction than the other end, and so by the time the edge is reached the wave-crest is parallel to it.

*The ocean circulation.* It has been customary, under the heading of currents, to pass in review the surface movements of the ocean only or, at most, to mention the surface currents moving one way and a deep-seated compensation movement called the ' creep ' going the other, as if these two horizontal movements were wholly unconnected with one another. It is most important to realize that these form only parts of the general circulatory movement of the whole mass of waters, the main cause of that circulation being the varying temperature of the ocean at different

depths; in a word, it is due to Convection. Except near the surface, this general movement is extremely slow; clearly, therefore, the surface currents must be ascribed to some other cause than temperature differences. This cause is the force and direction of the air-currents, and the effect of these on the waters is so great that, if it were not for intervening land-blocks, which hinder the water more than the air, the currents of the two would be identical. As it is, a map of the one gives strong indication of the course pursued by the other. As, then, the movements of the atmosphere have more to do with the surface currents of the ocean than has anything else, and as the surface currents are the only ones of geographical importance, reference must once more be made to these air-currents (see p. 84, fig. 25).

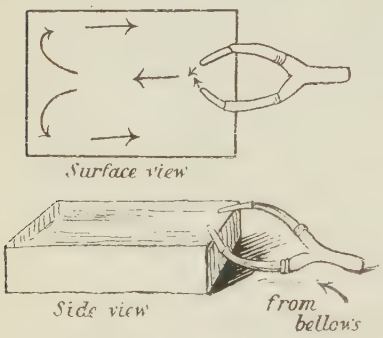



Fig. 54. Diagram of Apparatus needed for illustrating Surface Currents.

The rough plan of the air-currents shows the trade-winds blowing from north-east and south-east within the tropics. Clearly the actual effect of these two winds upon the water surface is the same as would be produced by one wind blowing westward. What this effect is the following experiment shows:

*Experiment proving course of currents* (Fig. 54). Take a shallow trough filled with water and sprinkle sawdust on the surface of the water. Additional apparatus needed is: a pair of foot-bellows, a Y-piece of glass-tubing, connected by rubber tubing with two glass tubes, which are drawn out to a fine bore. The tubes are arranged so that the air-currents from them converge and meet. A current results along the 'equator', as shown by the sawdust, and a compensating drift is set up.[1]

The sides of the pan form an obstacle to the direction of the currents, as do the continents, and the final result is a practically circular surface-flow or eddy in the two halves of the pan, in opposite directions. This is exactly analogous to the effect of the trade-winds on the surface of the ocean.

[1] The same effect can be watched in a mill-race by throwing in pieces of wood.

These strong regular winds, blowing towards each other and both trending westward, carry with them, in that direction, a huge volume of surface water, warmed by exposure to a tropical sun. This current, partially separated into two by a small counter-current, is called the equatorial current, and flows parallel to the equator in a westerly direction until it meets with obstacles in the form of land-blocks. It then splits, the main mass being forced northwards or southwards into higher latitudes. Here it falls under the influence of the anti-trades, which carry it with them, causing it to veer round and go in an opposite direction to its original course. Then, meeting with land again on the eastward side of the ocean-basin, it again splits, the main mass passing towards the equator. The net result is a superficial movement of rotation, clockwise in the northern hemisphere, counter-clockwise in the southern.

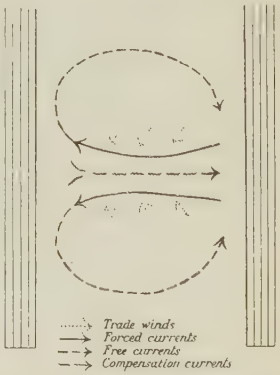



Fig. 55. Diagram illustrating Ocean Currents. (After E. de Martonne.)

This is clearly represented by De Martonne (fig. 55). Thus, the two great oceans that stretch both sides of the equator, the Atlantic and the Pacific, are each divided according to their surface movements into a northern and southern basin, each half having a great eddy-like current washing round its shores, with a comparatively peaceful part in the centre. The Indian Ocean would be represented by the southern

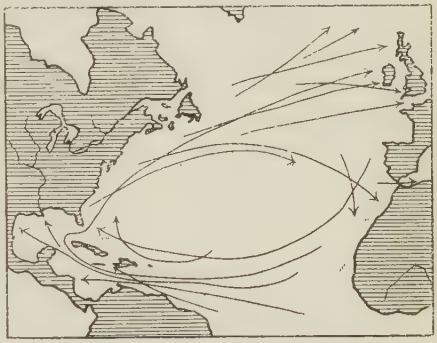


Fig. 56. Bottle-tracks in North Atlantic. (After pilot-charts.)

half only, except that, at times, its currents are reversed by the strong seasonal winds, the monsoons (see p. 89).

The map on p. 157 (fig. 56) of bottle-tracks in the North Atlantic is obviously in accordance with the above description of the movements.[1]

The currents hitherto described are the warm currents only. They have a very marked effect on the distribution of surface temperatures in the ocean, and some, doubtless, on the climate of the adjacent lands, though this is mainly dependent on the winds. The currents retain their warmth even within the polar circles, where the water has been traced as a thick warm layer, immediately beneath the cold surface waters.

The warm eddy in the North Atlantic, which spreads fanlike over a good part of the surface, has long been famous under the name of the 'Gulf Stream', and to it has been ascribed the mildness of the climate of the western part of the British Isles and Norway. The name has practically been repudiated in America, although it seems hopeless now to try and eradicate the two following beliefs :

1. That *all* the water has actually flowed through the Gulf of Mexico and there become heated ;
2. That the climate of our islands is directly due to the Stream itself.

For several reasons, however, it seems best to discard the term. In the first place, the bulk of the equatorial current does not flow into the Gulf of Mexico, but is turned northward by Florida and then sweeps broadly across the Atlantic. (2) The actual current in the Gulf is not always in the same direction, and when it is reversed our climate does not change. (3) More exact geographers distinguish between drift and stream currents, the main part of the Gulf Stream being drift. According to their accepted definition, a stream current flows rapidly in a comparatively narrow space with well-defined boundaries, like a river between its banks, whereas a drift, such as that which crosses the mid-

[1] In 1904 a bottle-track was traced from the north of New Zealand for a distance of 10,700 miles. This was traversed in 1,271 days, averaging about 8½ miles a day.

Atlantic, is broad and shallow, flowing only about 10 or 15 miles a day or even less.

We have now dealt with the currents which are usually warm and are carried along by the trade and anti-trade winds, but a glance at the wind-plan shows that less important currents should flow equatorwards and westward with the polar winds. This mass of colder water, on reaching lower latitudes, tends to sink below the northward flowing mass from warmer regions and finally reaches the sea-floor. In the southern hemisphere, which is unencumbered by land, this has been traced nearly as far north as the equator. The extent of these colder currents, on the surface, is always insignificant, but occasionally they flow side by side with the warm current, and the fact that they tend to cling to the land has a marked effect on the climate along their shores.

These horizontal movements of the upper layers prevail to a depth of 50 to 75 fathoms ; they are of the utmost importance in relation to navigation, and are consequently the only part of the great movement of ocean circulation that has long been studied and mapped.

We must, however, realize that the axiom of Varenius, 'si pars oceani movetur, totus oceanus movetur', is absolutely true, and this wind-affected surface portion is only a very small fraction of the whole. Apart from this, the general movement of circulation is due almost entirely to differences in temperature, but in a slight degree also to the fact that evaporation makes the water salter and consequently denser. Hitherto, we have had the fact of the horizontal movements impressed upon us, namely, the surface flow of warmer waters towards the poles and the compensatory movement of polar waters equatorwards. These two movements constitute only part of a great general system. The surface waters move horizontally polewards ; in so doing they become cooled and travel gradually downwards. In the depths they curve round and form part of an immense slow deep-water movement from poles to equator. The equator being reached, the constant removal of the surface waters impels an upward flow of water from the depths. This, on reaching the surface, gets heated in its turn,

and so the circle is complete. Thus, in each hemisphere, we have a vertical rotary movement of the waters, which receives its main impetus from a source of energy outside itself, namely, the air-currents. The varying rate of movement in this great system is very striking. Thus, the surface water takes 80 days to travel from the equator to 30° latitude, whereas the deeper water would creep along the sea-floor the same distance only in 150 years. From 3,000 metres depth the ascending water takes 50 days to reach the surface.

The following diagram (fig. 57) is an ideal vertical section of the Atlantic Ocean. It shows the actual circulatory movements of the waters in the two hemispheres and the relations of the cooler and more heated waters. It cannot show the differences

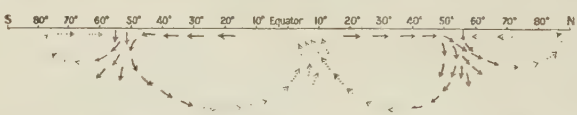



Fig. 57. Diagram showing General Circulation of Waters of Atlantic Ocean. Solid arrows indicate relatively warm water and dotted arrows relatively cold water. (After Sir John Murray.)

in the rate of movement, which have been mentioned already as very great.

*Tides.* The old Chinese writers say: the waters are the blood of the Earth and the tides are the beating of its pulse, or again, the Earth like a living body breathes and the rise and fall of the tides are the heavings of its breath. These statements reveal the Chinese as poets but hardly as scientific thinkers; indeed they were not nearly so advanced in this kind of knowledge as the people of the West. The Greeks and Romans, in spite of the fact that their nearest sea was tideless, yet in this respect, as in all else, were quick to realize the existence of the phenomenon and to grasp to some extent its meaning. As early as the time of Strabo, something of the periodicity of tides was known, for he quotes Posidonius (B. C. 135–51) as having proved that there was a daily, monthly, and yearly movement of the waters, due to the influence of the Moon. The early

candinavians knew this also and perhaps even sooner, for ne of the Icelandic Sagas mentions a connexion between this eriodic movement and the movements of the Moon.

No actual work was done in this direction and no theories ere offered until the time of Kepler, who recognized that the ovement was due to the Sun and Moon, but attempted no xplanation of the fact. Galileo stigmatized Kepler's view as eing mere empiricism and himself ascribed the tidal movement o the rotation of the Earth. No real solution was proposed ntil the publication of Newton's *Principia* in 1687, and—to uote Darwin—' this work affords the firm basis on which all ubsequent work has been laid '. Later, various scientists took p the subject, first Laplace, then Lubbock, Whewell, Airy, nd Lord Kelvin, but the most exact recent work is due to Sir eorge Darwin.

Although the theory of the Tides was not developed until quite ecently, means of calculating their height and periodicity for ertain ports have been known for centuries, but the methods mployed were kept a profound secret for a long time ; the est of those old tide-tables were those made in Liverpool and ondon, as they were produced by analysis of a very large umber of observations. In recent times, the tables made by ne Indian Government for the Indian Ocean, as also those made y the United States Government, are the most extensive.

The practical need of some knowledge of tides is obvious ; any oast fisherman must know when he can launch his boat and hen he can safely make for shore, and nowadays, when such arge ships are built and such an immense number of ports isited, the subject has become of even greater importance.

To give an adequate account of the Theory of Tides without mploying mathematical reasoning is difficult, yet this has been uccessfully accomplished by Sir George Darwin in his book n the subject.

We know that tides are large waves, of the same nature as, ut immensely longer than, wind-waves ; so long are they, in act, that each wave, consisting of crest and trough, may reach alf-way round the earth. Being a true wave, the movement of

the water is, as in the case of wind-waves, practically up and down, but in all the seas, bays, gulfs, creeks, and inlets, the raising of the level of the ocean naturally involves a flooding in and the depression a flowing out. This does not mean that on one side of the earth it is high tide everywhere at the same time, for water takes time to flow and is greatly hindered by friction, owing to irregularities in the bottom and sides of the basin. Observing from land, we call it the ' flow of the tide ' when the water approaches the shore, ' the ebb ' when it recedes. When the highest limit is reached, the tide is ' high ' ; it then ' turns ' until it has reached the lowest limit, ' low tide '. High tide and low tide alternate about every six hours, consequently in about 24 hours we have two high tides and two low tides. These do not occur at the same time every day because the interval between two succeeding high waters is, on the average, about 12 hours 25 minutes.

For the water to be raised up like this, it must be acted on by a force outside the Earth. There are, in the Solar System, only two outside bodies that could have this effect—the Moon because it is comparatively so near, the Sun because it is so large ; for the attraction one body has on another depends on two things, its size and its distance.[1] The Sun's attraction for the Earth is much greater than that of the Moon, but the latter, because it is much nearer, is the chief factor in the production of tides. For tides are caused by the *differences* between the attraction of the tide-producing body :

(*a*) On the waters on the near side of the Earth ;

(*b*) On the solid Earth itself ;

(*c*) On the waters on the far side of the Earth.

It is evident that these differences are *proportionally* much greater in the case of the Moon, which is distant about 60 Earth' radii, than in the case of the Sun, which is distant about 23,500

[1] The Solar tidal force should be 25½ million times as strong as that of the Moon because of the Sun's greater weight, but only one 59-millionth part as strong on account of its greater distance. Hence the actual tide-generating force of the Sun is about 25½ 59, or a little less than half that of the Moon. This ratio varies, as the distance of the Moon and the Sun from the Earth is not constant.

Earth's radii. It may also be noted that the interval between successive high tides is half a 'Moon's day' (12 hours 25 minutes), not half a 'Sun's day' (12 hours). This may be regarded as conclusive evidence of the predominant effect of the Moon.

To take the case of the Earth and Moon only (fig. 58), the attraction of the Moon at A is greater than that on the Earth as a whole, which may be considered as, on the average, equal to that at the centre B, and this again is greater than the attraction of the Moon at C. The Moon and Earth revolve round their common centre of gravity, G, which is about 1,000 miles beneath the Earth's surface, the Earth being so much bigger than the Moon. As a consequence of this revolution there is a force tending to make the Earth as a whole fly out of its path, the Moon's attraction on the Earth as a whole being just sufficient to keep it in its path.

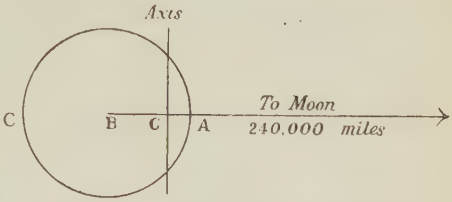



FIG. 58. Diagram illustrating Moon's Attraction on the Earth.

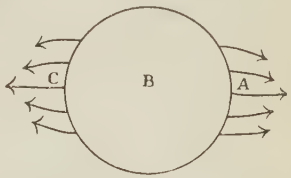



FIG. 59. Diagram to show Horizontal Component of Tide-generating Force. (After Sir G. Darwin.)

On the near side, the Moon's attraction is greater than this deflecting force and a tide-generating force, due to the excess of the one over the other, is set up towards the Moon. On the far side, the Moon's attraction is less than this deflecting force and a tide-generating force is set up away from the Moon.

At the points A and C (fig. 59), where the Moon is in the zenith and nadir respectively, this force is vertical; it cannot therefore move the waters horizontally and it is not great enough to overcome gravity. At other points, not immediately in a line joining the centres of the Earth and Moon, the direction of the force will not be vertical and will have a horizontal component. It is this horizontal component of the tide-generating force which really causes the tides, and *if the Earth did not rotate*, or

*rotated very slowly*, it would tend to produce a tide which would have its highest point immediately under the Moon. The friction due to the rotation of the Earth, however, complicates matters, and the high water in the open ocean does not occur when the Moon is on the meridian, but some hours after its passage. The tidal friction also helps to account for the ' lag '. Darwin states that if the water covered the whole Earth to a sufficient depth, the tide crests would be immediately under the Moon.

As has been mentioned above, the Sun also has some influence, though less than that of the Moon, owing to its extreme remoteness. When the Sun and Moon are on the same side of the Earth, i. e. are pulling in the same direction, the influence of the Sun, added to that of the Moon, produces a marked effect, the tides being then both higher and lower than at any other time. These are called the ' Spring tides '.

When the Sun and Moon are at opposite sides of the Earth and pulling opposite ways, the same effect is produced, the Sun's pull being along the same line, so that again its pull is added to the Moon's. Thus the highest high tides and the lowest low tides take place at Full Moon and at New Moon or at ' full and change '.

When the Sun and Moon are pulling at right angles to each other, i. e. at first quarter and last quarter of the Moon, the resultant force still produces a wave towards the Moon and on the side away from it, but the tides are neither so high nor so low as when Sun and Moon are in one line. The tides so produced are called neap tides (i. e. nipped).

Thus, every lunar month, there are two periods when the times of solar and lunar high water coincide, i. e. at New and Full Moon, these being the periods of greatest range, resulting in spring tides; alternating with these are two periods of least range, producing neap tides, the highest and lowest tides of all being nearest the equinoxes and their range decreasing away from the equinoxes. As a matter of fact, however, there are only a few places where the change of Moon and the high tide agree exactly; moreover, the actual case, as observed on the shores, is further complicated by the interference of land masses and

the unevenness of the sea-floor. If there were no land masses and the ocean extended over the entire surface the whole question of tides would sink into insignificance, for the tides would be negligible in height and almost inappreciable, not more than about 3 feet at most. The effects, however, of the interferences mentioned are so far-reaching as to have become of both geographical and commercial importance. Their results are mainly twofold :

1. The tidal wave is retarded in some places more than in others ;

2. The waves, forcing their way over irregular surfaces and through narrow channels, tend to become piled up in some parts, so that in those parts their height is very much above the normal and the rate of rise and fall is greatly accelerated.

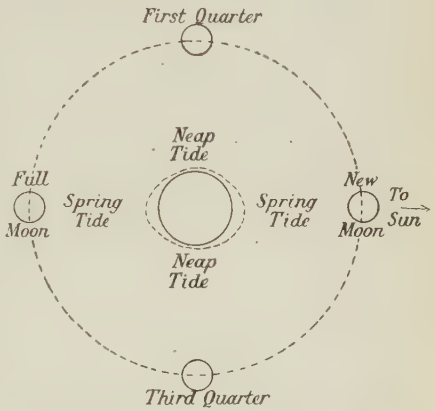



Fig. 60. Diagram to show Spring Tides and Neap Tides.

But as these factors are constant, their effects are also constant ; and it is found that, at any given place, the interval between the passage of the New Moon over the meridian and the occurrence of high water when not interfered with by the winds is always the same. This interval is called the Establishment of the Port, and for London Bridge its value is 1 hour 58 minutes. In *Whitaker's Almanack*, the time of each high water is given for London Bridge for each day in the year. There is also a table giving the difference between the time of high water at each of the important ports and that at London Bridge. These differences are called the Tidal Constants for these ports. With these two tables, it is possible to forecast the time of high water, but it must be remembered that winds may have considerable retarding or accelerating effects.

Charts showing the march of the tidal wave throughout the world were first calculated and plotted out by Whewell and Airy.[1] These charts of co-tidal lines, as they are called, claim to show, from observed times of high water in various parts of the Earth, how the tidal wave travels over the ocean. These maps are only very rough—their makers were not even in a position to realize how rough—but, so far, no attempt has been made to construct better. The chief drawback is that in the part of the world where tidal conditions are most normal, i. e. the Pacific Ocean, no data were obtainable.

Special and important results of the retardation of the tidal wave are the following :

Owing to the friction of the sea bottom in shallow places the water is piled up so that the tidal wave, instead of being only about 3 feet in height, is much more than that. This is especially seen in estuaries where the water is squeezed between rapidly converging shores and the depth of the channel diminishes at the same time ; at Cardiff, for instance, the difference between high and low tide is about 40 feet at the spring tides. Sometimes, when the tide meets a strong stream, the head of the tidal wave stands up in a ridge above the level of the river water. Examples are the great bores of the Ganges and Yangtse-kiang, the pororoca of the Amazon, the mascaret of the Seine, and the more familiar bores of our own rivers, the Severn, the Dee at Chester, or the eagre of the Trent. A bore forms where the outlet of the river is swift and is greatest at the spring tides, being largely increased in the Severn and Dee if there is a strong westerly wind blowing upstream.

In consequence of the piling up of the waters, the tidal currents gain very much in strength and swiftness. For this reason, when forced into narrow channels, they have very great powers of erosion and also completely clear some estuaries of sand, keeping them open for shipping. Certain ports, such as Rouen, Nantes, Bordeaux, London, and Hamburg, were established approximately at high tide range, and possibly this was a factor in determining

[1] Whewell, *Phil. Trans. Roy. Soc.*, 1833 ; Airy, ' Tides and Waves ', *Encyclopaedia metropolitana.*

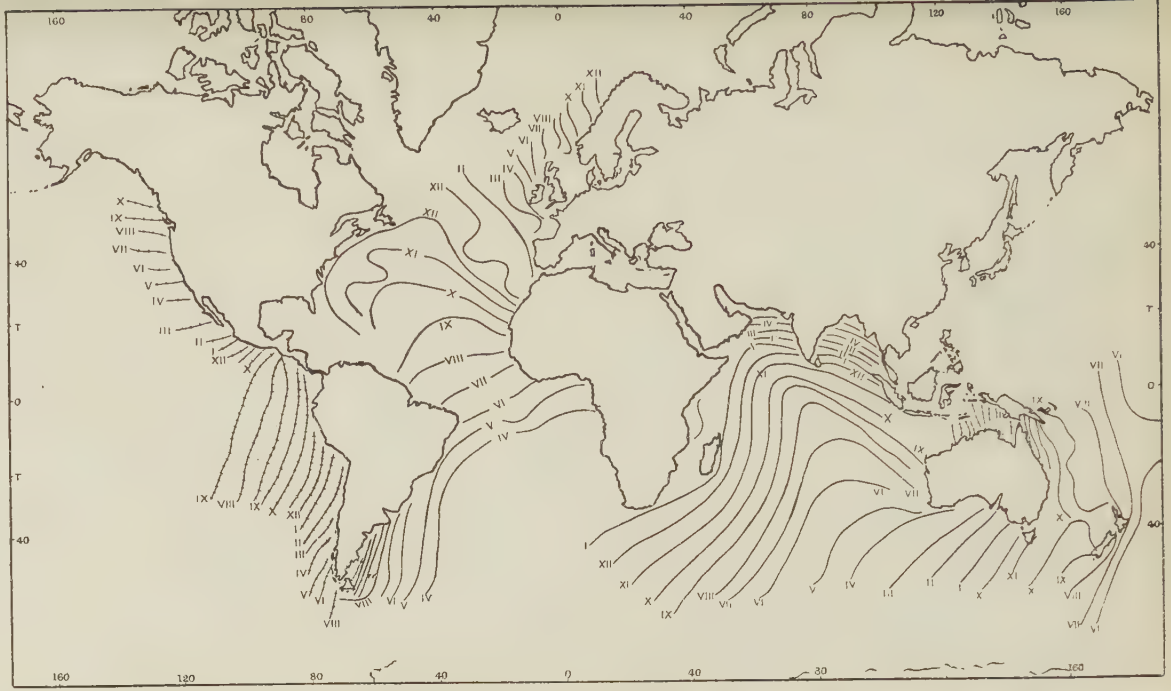



FIG. 61. Chart of Co-tidal Lines showing Retardation of Tidal Wave owing to Land Interference. The Roman numerals indicate the hours. The dotted lines are partly based on conjecture. (After Airy.)

their position. The remarkable force and swiftness of the tide in the Bay of Fundy is well known, and so great is it that steam trawlers were used there for fishing long before they came into use elsewhere. When a rapid current is produced by the tide in a narrow passage, it is sometimes called a race, e.g. the Alderney race. Until the removal of rocks by blasting prevented it, there was, between the mainland and Long Island, a tidal race which interfered with the utility of New York harbour.

Another curious effect of land interference is that by one tidal wave overlapping another the number of tides may be halved. For this reason the Gulf of Tonkin, the Gulf of Mexico, and the Adriatic have only one high tide in twenty-four hours instead of two.

Occasionally the opposite effect is produced. The tidal wave from the English Channel, passing north of the Isle of Wight both by the Solent and by Spithead, gives Southampton four high tides in twenty-four hours instead of two, thus greatly enhancing its value as a port.

The splitting up of the tidal wave by intervening land has another result in the formation of sand-banks, sometimes of great extent and often of varying position, which may render navigation difficult.

These tidal waves, which are regular and whose course is known, must not be confused with the so-called tidal waves of about 30 feet high, which are met with occasionally in mid-Atlantic, and travel singly or only two or three together. These are due to the existence somewhere or other of earthquakes or of submarine volcanic activity, and their coming cannot as a rule be either foretold or accounted for. They should, properly speaking, be called earthquake waves.

# SECTION V. THE LITHOSPHERE

## XVI. General Account

HAVING gathered some general notion of conditions on the ocean-floor, i. e. the gently undulating nature of its surface, the monotony of the oozy deposits, the uniform cold of the submarine climate, the darkness of the day, lit only by reflections from the phosphorescent surfaces of the silent inhabitants—it is with relief we turn to the utterly different and strongly contrasting conditions which obtain on the land. Here we have clearly delineated heights and lowlands, surfaces of extreme variety formed by a wealth of different materials, rapid and intense alternations of heat and cold, light and darkness, the light being derived from bodies outside the earth. Life on the land is both active and sluggish, noisy and quiet, so, 'variety being the spice of life', it is to the land we look for variety in living forms, and amongst these for the most highly organized animals, with the strongest instincts and highest intelligence, of which man, so far, is the leader and chief.

The term lithosphere, which heads this chapter, really comprises the whole solid globe, as distinct from the hollow gaseous sphere which surrounds it and is called the atmosphere, and the hollow incomplete aqueous sphere, the hydrosphere, which partially encloses it. The science of geography, however, is not concerned with the whole of the lithosphere, but only with its surface, and more particularly with that part which is not submerged and is designated 'land'.

The land lends itself to the use of man in many ways that the realms of sea and sky do not, and herein lies its geographical significance. Although the air has been utilized by man in the past for obtaining power, as in windmills, or during the war for obtaining nitrogen, and is now beginning to be still further used for purposes of locomotion, yet he derives no nourishment from it directly, and except fairly near the Earth's

surface, his very existence in it is impossible.[1] The ocean is in constant use as a highway for vessels and a considerable amount of food in the form of marine animals is obtainable from it, but man cannot live in it or even on it as a permanency; to obtain sufficient food he must be frequently in touch with land. The land, on the other hand, is man's natural home; its surface is fairly and increasingly under his control. He cannot actually remove mountains or level up valleys, but he can surmount, circumvent, or penetrate the former and, in the light of modern science, so alter conditions in the latter as to render the hopelessly barren, fertile and productive. All over the earth's surface, which we call the 'world', the natural products of the land, whether animal, vegetable, or mineral, are being utilized, and fresh resources are constantly being discovered and turned to account. So greatly has the natural condition of the Earth's surface been complicated by man, that it has been customary hitherto to divide geography into two distinct sections and to discuss each quite separately. Thus 'physical geography' deals with the form and features of the Earth and the natural processes modifying them, whereas 'political geography' records the changes made by man, the works he inaugurates, the surfaces he cultivates or forms into feeding-grounds, the cities he builds, the divisions he makes, and the intercommunications he establishes. This method of dividing up what should be one subject is artificial, and results in that complete estrangement of cause and effect which is disastrous to any kind of scientific treatment.

For the sake of simplicity, it is best to consider first the Earth as man finds it and as it changes before his eyes from day to day, explaining, without straying too far into geology, why he finds it thus and what natural changes effect its variation and decay. This physical condition forms the basis of the whole study, and we soon see that man, having discovered this foundation already laid, at once begins swiftly and skilfully to erect his rapidly increasing fabric upon it. The elaborations of this

[1] The world's record for height attained was in 1921 held by an American, Rowland Rohlfs, who in September, 1919, attained a height of 32,450 feet. This height has since been exceeded by Lieut. J. A. Macready, U. S. Army Air Force, who reached 40,800 feet, Sept. 28, 1921.

fabric must be dealt with in separate regions, so in the present work the treatment of the land is limited to the establishment of broad principles.

Before attempting to give any definite classification of land forms, it is necessary to explain that difficulties arise owing to there being at present no universally accepted nomenclature in this subject. Long before the close of the nineteenth century, meteorology, oceanography, anthropology, animal and plant geography had become established as definite sciences, each in itself a branch of physiography. The study of land forms, however, is far newer and, although the changes that go on have been well worked out by many, yet the original basis of the whole has hardly been dealt with on broad lines. A good many terms have been introduced into the subject by French and American writers, and Professor Suess, in his comprehensive work, has familiarized us with others, but no world-wide classification or nomenclature has been attempted. The name of this branch of the science is not even fixed; the suggested 'geomorphogeny' means too much, whereas 'orography' and 'topography' mean too little. The term 'geomorphology' is nearest, but even that should deal with rather more than the surface, so it seems simplest to speak of this part of the subject as a study of land relief and to make use of terms that more or less explain themselves or are in fairly general use.

The broad principles upon which our present study of the lithosphere's surface are based are the following:

1. The differentiation of the surface of the lithosphere into topographic features of the first order;

2. Consideration of the natural features and divisions of the subaerial part of the surface more particularly;

3. The differentiation of these into topographic features of the second and third orders;

4. The dependence of these forms on the modelling agents, atmospheric, fluviatile, and marine, constantly at work, with spasmodic, volcanic, and seismic action in certain regions;

5. Special results due to the modelling agents where the climate is other than temperate.

## XVII. Land Forms of the First Order

Taking first the differentiation of the lithosphere into topographic features of the first order, we see that its entire surface seems to fall naturally into two sections :

The subaerial land surface.
The suboceanic land surface.

The geologist realizes at once that this separation is more apparent than real, and its adoption as a means of differentiation would be arbitrary, this particular boundary-line having altered its position repeatedly throughout the whole period of the earth's history. In actual fact, a certain part of the surface now submerged is organically part of the land mass, and we therefore distinguish three areas : [1]

(*a*) The oceanic area, consisting of the ocean basins and covering about one-half of the surface of the globe. This is far more uniform in depth than the land surface is in height, and varies between 12,000 and 18,000 feet below sea-level.

(*b*) The continental area includes with each continent the narrow submerged shelf which encircles it and which often bears on its surface subaerial features, such as continuations of river-valleys, submerged forests, &c. The average depth of the continental shelf below sea-level is about 100 fathoms, but it often slopes gently on its outer edge to a depth of about 300 fathoms (see fig. 43).

(*c*) The continental slope connects the oceanic and continental areas. This occupies rather less than one-eighth of the globe's surface, is usually steep, and extends downwards to mean sphere level,[2] a depth of about 10,000 feet.

[1] Sir John Murray's classifications ; see Murray, *The Ocean*.

[2] Mean sphere level is an imaginary line cutting the slope between the elevated and depressed areas at 10,000 feet below present sea-level, so that the volume of the elevations above the line equals the volume of the depressions beneath it. Mill points out that, by a coincidence, half the area of the earth's surface is above mean sphere level and half below it.

These three surface members of the lithosphere constitute the opographic features of the first order; their differences are lifferences of elevation, of form, and of continuity. The oceanic rea and the continental slope are wholly submerged, continuous, nd have definitely suboceanic contours. The continental area s discontinuous, being broken up into more or less isolated locks; it is practically entirely above sea-level except for the narrow encircling strip called the continental shelf, and the part above the sea has subaerial contours, which are also ust traceable on the continental shelf.

The differences between subaerial and suboceanic surfaces

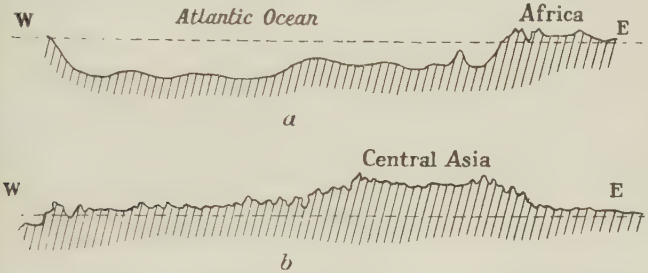



Fig. 62. Sections to show contrast between Subaerial and Suboceanic Contours. *a*. Section across the Atlantic along the 25th parallel of N. atitude; *b*. Section across Asia along the 35th parallel of N. latitude. Vertical height much exaggerated. The broken line shows sea-level in each case. (From De Lapparent after Heiderich.)

are well marked and unmistakable. Some appreciation of these is obtained by studying the profiles given above (fig. 62); it must, however, be remembered that few data are obtainable for the study of suboceanic surfaces. Here we see that the land surfaces of the globe show universal marks of the atmosphere's influence upon them, including that of running water, also derived from it. The characteristic feature of this is the formation of *concave* curves and of well-marked outlines; active changes, which are constantly going on, give a general effect of *degradation* or grinding down, by which the surface is being reduced nearer and nearer to sea-level. The ocean areas, on the other hand, whose floors are bathed by still or slowly moving

water, are in a more passive condition. The characteristic mark of subaqueous influence is the retention of *convex* curves, of blunt-featured outlines, and a general effect of *aggradation* or levelling up, by which the surface is like the land areas only in the contrary sense, being gradually, through the ages, brought nearer to sea-level. The general convexity of the suboceanic surface is due to the fact that the original form is there preserved comparatively unaltered, the ocean's influence being protective rather than destructive.

A leap into the distant future would probably land us on an earth resembling in many ways the planet Mars, almost featureless, for the planet's face, unlike the human one, becomes smoother with age.

The slight changes that are discernible even during a human lifetime also give indications of these levelling processes ; thus we see cliffs worn away, mountain-peaks splitting and their fragments falling and accumulating, river-mouths being silted up, and various other minor indications of the same general trend.

In the course of geological time there have been various changes in the distribution of land and sea, but Professor James Geikie believed that certain portions of the land, which he called 'world-ridges ', came above the surface first, and although at times submerged, have remained regions of dominant elevation ever since. These world-ridges are important, as their position determines the sphere of influence of the great oceans, and the slope of the land being generally towards an ocean, it is possible, by reference to a map, to see at a glance which portions of the land fall within each ocean's influence, and to note also that certain tracts are removed from the influence of any ocean.

### *Consideration of the Natural Features and Divisions of the Subaerial Part of the Surface more particularly*

Passing now to more detailed treatment of the lithosphere, we can neglect the oceanic area and continental slope as being more appropriately handled in the chapters devoted to the

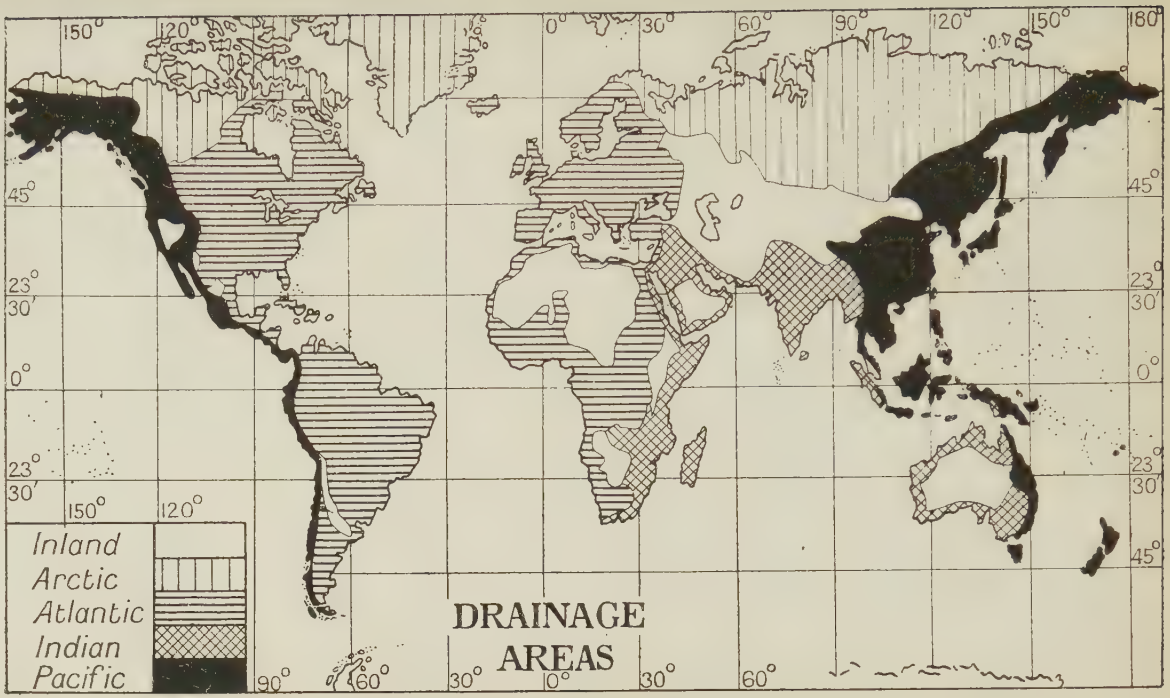



FIG. 63. Drainage Areas: Atlantic, Pacific, Indian, Arctic, and Inland.

hydrosphere, and concentrate our attention on the continental area alone. This, consisting of the present land-areas and the now submerged continental shelf, makes up about one-third of the Earth's surface. The two main points to be studied in this connexion are :

i. Outline.
ii. Relief.

The outline of the continental area (shown approximately in map, fig. 43) should be compared with that of the continents. The inclusion of the continental shelf simplifies the outline and shows which portions of the land are organically connected, like the opposite coasts of the English Channel (La Manche). Its presence also elucidates the configuration of coasts (contrast Norway or Brittany with the Landes) and the relations with adjacent islands (i. e. the British Isles with the mainland, &c.).

i. *Outline.* The significant features of outline are :

1. The aspect of the land and the direction in which the coast-line runs. These affect climate directly, and consequently also fertility : compare, for instance, Labrador and British Columbia.

2. The nature of the outline. A regular unbroken coast-line presents difficulties for navigation, as there are no harbours ; it is also unfavourable climatically, for, if it is elevated, moisture-laden winds cannot penetrate inland, as in the case of the south part of Western Australia. A broken coast-line may offer excellent harbourage for ships and also affects the climate advantageously, moisture-laden winds being able to penetrate far inland, as, for example, in Norway.

3. The nature of its substance, whether of hard rock or soft. If rocky, it may endanger shipping, as in Cornwall, Wales, or the west of Scotland, and also, being usually elevated, it may assist rainfall by forcing moisture-laden winds upwards, thus causing water-vapour to condense. If soft, it may or may not be favourable for navigation ; when the soft material is frequently shifted by currents it becomes dangerous—for example, the sand near Calais harbour, which sometimes blocks the entrance. This

kind of coast may also be somewhat arid, as there is nothing to induce rain, and shifting sand blown about by the wind is not amenable to cultivation, e. g. the Baltic coast of Germany, the Landes of France, &c.

Outline is not a permanent feature; the sea makes great inroads on some coasts and the outline is altered, as in Holland. Again, large tracts of land may be reclaimed, as in the English Fen country. Moreover, warping of the coast lines, i. e. local elevation or depression, takes place, as was recognized long ago in Sweden and as was also shown by Darwin in his researches on the coast of South America. The most important changes in this direction, from man's view-point, are those which affect the use of ports. Adria is now situated several miles away from the Adriatic Sea to which it gave its name; the Tiber no longer admits of vessels of any size sailing up to Rome; Chester, King's Lynn, and other former ports are so no longer, and the Cinque Ports are most of them useless for the same reason.

Outline, even taken apart from relief, has a potent influence on the existence and well-being of all living things, particularly the human race. Sea-girt areas are often more favourably situated as regards climate than land-locked ones in similar latitudes; compare the British Isles and Central Russia. The neighbourhood of the sea has a tempering influence on climate and is likely to induce rain; land-locked regions, on the other hand, have a more extreme climate and possible scarcity of rain. In the matter of intercommunication also, proximity to the sea has its advantages. In spite of the difficulties of navigation, history tells us that the inhabitants of maritime countries, even when remote from one another, speedily found means of intercommunication. Thus the sea may induce intercourse where the land acts as a barrier, for lands separated by mountains or deserts remain isolated from one another, even though, geographically, they are near. It is true that the Romans used the Alpine passes and established military stations and roads, and that a certain amount of trade was carried on through them in early times as, for instance, the amber trade between the Baltic and Italy, yet by far the most important trade in the Middle

Ages was that carried on between Venice and the Hanse towns by sea. Again, the Moors did not swarm over into Central Africa, but turned their faces across the sea to Spain and ravaged the coasts of Italy. Indeed, in regions of high relief the land becomes an isolating factor; peasants of adjoining valleys in Switzerland and Tirol, parted from one another by only a few miles of upland, have often developed along entirely different lines as regards language, costume and customs generally, more than would have been the case if they had lived on islands separated by as many miles of sea. Thus outline may be considered as having played a very important part in the development of the various human races and in affecting the rate at which they achieved civilization.[1]

ii. *Relief.* Relief, in that it affects the whole land surface and not its margins only, is of far greater importance than outline. The main part of the continental area has a range of elevation from 6,000 feet above sea-level to 600 feet below and an average altitude of 2,300 feet above the sea. Certain portions of the surface attain a much greater height than 6,000 feet, but their area is very limited except in Central Asia. Disregarding everything except the main feature of the relief, we notice that the land slopes almost invariably towards some ocean. Really the land thus sloping and the ocean itself together constitute a geographical unit, so that the grouping into continents, so long maintained, is an artificial and arbitrary plan, which should, scientifically speaking, be abandoned.

In proof of this, we can see at once that the seaboard lands on the two sides of the Pacific Ocean have more in common with one another, structurally and climatically, than have the Atlantic and Pacific seaboards of North America. Again, a careful scrutiny of the lands flanking the Atlantic reveals the fact that the relief features of either side correspond, for the same uplift (the Hercynian uplift of geologists) is believed to have produced the Appalachian and the Armorican ridges (fig. 64).

[1] At the same time, migrations of peoples and transport of troops, until the time of the Great War, took place by land; for fuller account of this see section on the 'Biosphere'.

In the Mediterranean the seaboard is cut off by high mountains from the interior, both on the north side and in the Atlas region. Here the climate and vegetation of the opposite coasts agree, and the Greeks and Phoenicians cruising through these waters founded their colonies on either side.

Now that each continent has become so established in the popular mind as a separate entity, it is difficult to wipe out all preconceived notions and to resort to what would be a broadly scientific method of study, i.e. to treat each ocean—with the lands surrounding it, the mountains, plateaux, and plains sloping down to it, the rivers flowing into it, and the peoples inhabiting and cultivating the whole area under its influence[1]—as a geographical unit, separated by the highlands, which generally form a definite boundary between it and the next adjacent unit. In the present work, however, an attempt will be made to keep sight of this broader view, so the distinguishing features of each land mass will be considered chiefly with reference to the ocean to which it belongs.

Fig. 64. Sketch to show Continuation of Hercynian Uplift on Western Side of the Atlantic Ocean.

Taking relief more especially into consideration, a careful examination of the map (fig. 63) shows which portions of the land come directly under the influence of each ocean. The sphere of influence of the great oceans is determined by the position of the 'world-ridges' mentioned on p. 174. These ridges, as they now exist, form a high and almost continuous rim to each basin, practically all the land on one side of the ridge sloping towards and being directly influenced by one ocean and the land on the other side being similarly disposed towards

[1] This does not imply that races inhabiting opposite shores are alike ethnologically, but that their occupations tend to be similar.

another. Thus the great western world-ridge, which it is less confusing to call the New-World Ridge, is the more clearly defined and unbroken of the two, and forms one rim of the basin belonging to the Pacific Ocean. It extends the whole length of North and South America, nearer the west side than the east, and is continued into Antarctica by a shallow-water connexion with a promontory of the Antarctic continent, which projects towards South America. On the north this ridge is only separated from the eastern or Old-World one by Bering Strait, so that the northern side of the Pacific Ocean is nearly closed.

Across Bering Strait, one limb of the great eastern ridge, which to escape confusion is here called the ' Old-World Ridge ', forms the other side of the Pacific Ocean. This world-ridge is complex and has been compared to a horseshoe, but it is really like two horseshoes meeting or a horseshoe with ends frayed out and spreading fan-wise, thus : ⋋,[1] or we may call it a horizontal ridge, with both ends branching opposite ways.[2] The right branches of this ridge limit the Pacific's basin westward. Passing in several parallel ridges along the coast of Asia in a curving line from north to south, it continues through the islands and along the east side of Australia, ending in New Zealand and Tasmania. Even here it does not completely end, for an extension of Antarctica in this direction meets it in comparatively shallow water.

The southern half of this 'Old-World Ridge' bounds the wide semicircular basin of the Indian Ocean. The eastern portion of this has already been mentioned as part of the Pacific boundary, and is distinctly of Pacific type. The rest curves across Central Asia and extends along east-central Africa from north to south, terminating at the Cape. Here it also is opposed by an Antarctic projection, so that the basin is very slightly indicated on both sides to the south.

The northern horseshoe of this ridge forms the boundary between the basin of the Arctic Ocean and the northern part of the Atlantic Ocean.

[1] The slope may be compared to that produced by cutting an inverted saucer in half and reversing the positions of the two halves.

[2] See outline of Indian and Arctic Basins in map, fig. 63.

Across North America there is no division line between the Arctic and Atlantic Basins, hence the great comparative cold of the northern part of that continent and the far-extending influence of the warmer waters from the south.

*The Pacific Basin.* Considering each basin more in detail, we observe that the Pacific Basin is characterized, and also distinguished for the most part from all others, by the nearness of the ridge to the sea and the comparative steepness of the seaward slopes. On the American side the ridge approaches the coast quite closely, and the continental shelf being narrow and its slope steep, very deep water is found quite near the ridge. On the Asiatic side, where the continental platform is wider, the ridge is submerged in parts, and in others stands out as islands. Finally, in Eastern Australia, it again flanks the coast. The ridge itself marks a line of great disturbance of the earth's crust, so much so that the numerous volcanoes dotted along it have gained for it the name of the Pacific's 'ring of fire'. Earthquakes are also of frequent occurrence, and there are many signs of the coast having undergone a considerable amount of differential movement, that is, in some parts it has been raised and in others depressed. From recent observations it is found that, along the west of the American continent, elevation is now taking place; on the Asiatic side the coast is rising in some parts and sinking in others. A good many continental islands occur on the shelf on that side, e. g. the festoon islands of Asia, including Japan, the islands of the Malay Archipelago, of Australia, &c.; even the islands of Fiji and Tonga may be considered to continue the shelf, as there is a sudden plunge into deep water outside these. A few islands of the same origin are found on the eastern side, close inland, owing to the narrowness of the shelf. The islands beyond the shelf are oceanic, and have arisen from the sea-floor directly, owing either to volcanic and coral formation or volcanic only.

The fact that the Pacific Ocean is practically closed on the north prevents the colder Arctic waters from entering it, and the lines of the world-ridges that form its rim on this side being convergent, what land there is faces more or less southward. Comparatively speaking then, the Pacific lands are more for-

tunately disposed as regards climate than those of the Atlantic Basin. It is true that the ridges diverge widely towards the south, but even here the basin is closed in except for shallow water connexions and the breadth of the southern ocean places the land under oceanic conditions, which are less extreme than continental ones. Consequently the Pacific Basin, taking it all together, is climatically favoured, and when the land slope of the more temperate part is sufficiently wide, it supports a teeming population, as in China, but the ridge being almost everywhere near the coast there are, excepting again China, no vast areas of land subjected to the Pacific influence and no great navigable rivers flow into the ocean. Trade is carried on between the islands, but the traffic between the coasts is diminutive compared with that of the Atlantic, chiefly because so few great centres of population can exist along its narrow shores.

*The Atlantic Basin.* The Atlantic Basin presents a strongly contrasting picture. Here on the west the great ridge is far removed from the seaward edge, so that the basin's rim encloses vast stretches of land sloping towards the ocean ; these seaward slopes include the greater part of North and South America. On the east they consist of the Atlantic slopes of the British Isles, part of France and Spain, and a good part of Africa. A continuation of the great eastern or Old-World Ridge forms the land masses of Greenland, Iceland, &c., and partly closes in the basin on that side. Branches from this complex ridge run at right angles to the coast and reappear on opposite sides of the ocean, as for instance the Armorican ridge which, extending through Brittany and the north of Spain, is continued, according to Suess, as the Alleghanies and other features of the Appalachian uplift on the other side (fig. 64). Huge rivers, draining vast tracts of land, empty themselves into this ocean, and a large portion of the world's population inhabits the opposite sides of its temperate shores. In proof that the ocean promotes and does not retard intercourse, we need only quote the North Atlantic Basin, for English, Spanish, French, German, and the Scandinavian languages are spoken on either side. In addition to the rivers, large seas, bays, and gulfs open into the Atlantic,

these greatly adding to the length of the seaboard and connecting up numerous peoples and countries. The world's great markets are found around the Atlantic shores, and an immense amount of traffic goes on between opposite coasts, though there is little trade amongst the islands. We might call the Atlantic a continental ocean, as contrasted with the Pacific, which is an oceanic one. The difference seems mainly due to the fact that the one has broad sloping land margins facing east and west, and consequently habitable, while the other has, in the main, a comparatively narrow and often rocky rim.

*Basins of Arctic and Indian Oceans.* Partly bounded by the northern and southern limbs of the eastern or Old-World Ridge, we have the Arctic and Indian Oceans, curiously contrasted again. Here the broad, sloping and, in that sense, habitable land margin faces the former ocean, that of the latter being in great part narrow and rocky. Climatic conditions, however, are reversed, for the broad margin, instead of facing east and west, as in the Atlantic, slopes northward. So, although the land is, in part, not otherwise than fertile, and although large navigable rivers traverse the plains, the whole surface is subjected to the influence of a rigorous climate and, over the greater part of the region, plant growth is rare and difficult, animal and man finding a settled living almost impossible. There is, moreover, practically no traffic across the ocean and little regular trade with the islands.

The Indian Basin, as has been stated, is completely closed on the north and is not entirely open on the south, owing to the relatively shallow-water connexions between the southward projecting peninsulas and the Antarctic continent's promontories. The part of this basin that constitutes land does not easily admit of generalizations as do those of the Atlantic and Pacific. It has not the Pacific's narrow rim nor the Atlantic's wide slope, but something between the two. Where the ridge is remote from the ocean margin, the land-area thus interpolated consists of plateau and not plain. The plateau extends almost to the water's edge and there drops suddenly to a very narrow seaboard margin. This is the case in Australia, in the peninsula

of India, in Arabia, and Africa. In Further India and the islands, on the other hand, the basin is of Pacific type. The plateaux are for the most part arid; few great rivers cross them towards the ocean. On the north side of the ocean, however, the ridge approaches the coast on each side of the peninsula of India, i. e. north of the Bay of Bengal on the east and the Arabian Sea on the west. In this portion of the ridge great rivers have formed parallel to it, between it and the Dekkan plateau, and at their mouths ports have arisen. A brisk trade is carried on in the Indian Basin, but not so much between its own ports as between them and those of the Atlantic Basin. The symmetrical massing of land on the north and water on the south gives a regularity and reliability to climate and conditions generally, which imparts a unique character to the basin of the Indian Ocean.

Areas of inland drainage are not mentioned here as they are probably not of primary origin, and have simply lost the connexion which they once had with the sea.

*Tetrahedral theory applied to the world-ridges.* Another method of studying these ridges and one which is clearer for illustrative purposes is to revert once more to the tetrahedral theory. The tetrahedral model suggested by M. Michel-Lévy has its axis slightly inclined to the present position of the poles, and seems to give clearer indications of the lines of tetrahedral collapse than does that of Lowthian Green. The direction of these lines is best established by taking a small hand globe, such as that published by Messrs. Philip, and surrounding it with elastic bands exactly along the lines of the ridges of the tetrahedron given below (fig. 65). A globe thus arranged is of the greatest value as indicating the lines along which the tetrahedral collapse is supposed to have taken place. Then by using the net given (fig. 65) the tetrahedron itself can be constructed. The six-faced figure (hexakis tetrahedron) is here used, as showing more features than the ordinary tetrahedron; it would, in fact, constitute a stage between the globe and the latter figure. The model having been constructed, the following features emerge:

1. Each ocean is situated on a face of the figure, the centre

of the face being, in each case, in the centre of an ocean; on the other hand, the continents lie mainly on the edges of the

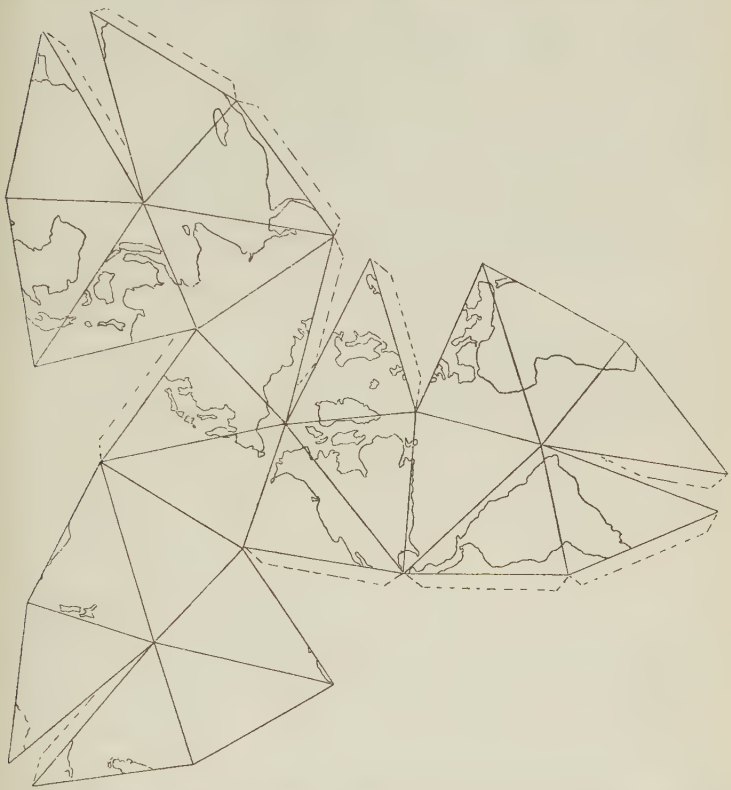


FIG. 65. Position of Ocean Basins and World-ridges illustrated by Tetrahedral Theory. The orientation of M. Michel-Lévy is used. (A small globe with the position of the edges marked by elastic bands should be used with this figure. If the base of each triangle is 2 in. the resulting figure will be approximately on the same scale as Philip's hand-globe.)

tetrahedron, each coign, or solid angle, of the simple tetrahedron emerging in a continent.

2. The three vertical ridges form the edges of the ocean basins of the three great oceans (counting the festoon islands and Australia, &c., as part of the Asian-Australian continental plat-

form). Each of these ridges coincides with a line of crustal weakness, that of Africa coinciding with the Great Rift Valley.

3. The horizontal ridge coincides with the Hercynian ridge on the Atlantic side, with the main central Asiatic ridge on the Indian side, and passes through the North Pacific on the Pacific side.

4. A little south of the ridge and parallel to it, is a median line of depression right round the world, passing through the Mediterranean, the Persian Gulf, south of India, through the Malay Archipelago and finally through the Gulf of Mexico.

5. Minor ridges correspond with the Ural Mountains, the Rocky Mountains, &c.

6. The outstanding portion of Antarctica coincides, in the main, with the three chief ridges.

Many other features, such as the distribution of earthquakes and volcanoes, are well illustrated by the use of this model.

## XVIII. Land Forms of Second and Third Orders

### *Topographic Features of the Second Order*

HAVING now dealt with the massing of the land-areas and their relations with each ocean, we next proceed to describe land forms of the second order, i. e. the different types of relief. For an exact description of these, it is usual to refer them to mean sea-level. On a British Ordnance Survey map this is the level of mean tide at Liverpool.

The principal types of relief may, for convenience, be grouped thus, although, as usual in nature, no hard and fast line can be drawn between them :

| *Subaerial forms.* | *Submerged forms.* |
|---|---|
| Mountains. | Continental shelf with islands. |
| Plateaux. | Continental slope. |
| Plains. | Ocean basin with islands. |
| | Ocean deep. |
| | (All of these are dealt with under 'Hydrosphere'.) |

Beginning from sea-level we have, raised but little above it, the plain, which is the most widespread land feature on the globe's surface.

Plains are surfaces of low level and of usually wide extent. Their existence depends partly on geological structure, that is to say, their even surface is often an indication of fairly level or only gently tilted strata beneath, and they are likely to be composed of the softer materials of the earth's crust. They cannot be definitely marked off from plateaux and may gradually merge into them. The surface of a plain most frequently has a gentle seaward slope and, where this slope has been gradually formed by the action of rain and rivers, it is called a peneplain.

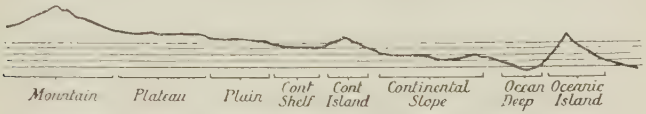



FIG. 66. The Relations between the different Land Forms. (Not to true scale.)

Plains are of two somewhat distinct types :

1. Coastal plains ;
2. Inland plains.

Coastal plains are formed in two ways :

i. By a slight raising of the continental shelf, either by actual earth movement or by accumulation of material brought by rivers, &c., from further inland ;

ii. By erosion or the wearing down of what has been higher land ; this is the kind that is usually termed a peneplain.

Coastal plains are of common occurrence and are very important from the human point of view. They become thickly populated for two reasons :

(*a*) If they have recently emerged from below sea-level their soil contains salts which are valuable for plant life. Hence arose the cotton industry of the southern United States.

(*b*) Their inhabitants have easy access to the sea, especially where the coast is indented by harbours or where the rivers flow out. In this way communication is established with the interior, and if the interior has products of value a great shipping trade

may arise; for example, the sea-board towns of the South Wales coalfield, those at the mouths of the Tyne and Clyde, also New Orleans, Calcutta and many other places.

The coastal plain is bordered on the seaward side by the ocean or sea and on the landward side by a sudden access of elevation, where it merges into the plateau. The line where rivers pass from plateau to plain is sometimes so well marked as to be called the Fall-line, and cities often arise at this point for two reasons:

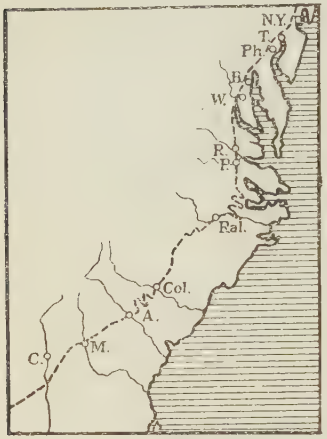



Fig. 67. Map showing the Fall-line in the Eastern United States, which fixes the position of twelve large cities. Falls occur at the edge of a plateau formed by the ancient harder rocks, so that water-power is available along this line. N.Y., New York; T., Trenton; Ph., Philadelphia; B., Baltimore; W., Washington; R., Richmond; P., Petersburg; Ral., Raleigh; Col., Columbia; A., Augusta; M., Macon; C., Columbus.

1. The river begins to be navigable below the falls;

2. Water-power is obtainable at the falls.

The best example of the Fall-line is seen in the eastern United States, where it fixes the position of twelve big cities.

In this case the Fall-line marks the limit of the harder rock, which forms the plateau above.

In Eurasia, the whole northern part of Europe (excluding Scandinavia) and Asia, continuous but for the Ural Mountains, is a broad coastal plain.

The big deltas at the mouths of some rivers are coastal plains in process of development. The whole of Lower Egypt has been built out in this way, as has also the platform on which New Orleans stands. In these two cases, commerce has gained by the formation of the plain, because the soil so produced is of great fertility, but when such a formation has the effect of cutting off a port from its piece of coast and placing it inland, then trade is injured. This has happened to Adria on the Adriatic, which now stands inland

on a coastal plain, formed by the junction of the deltas of the Po and Adige.

Coastal plains formed by denudation may be wholly infertile. When they are of marine origin, they are characterized by having on the landward side a cliff of the rock through whose destruction they have been formed. The sea-beaches of Whitby, Hunstanton, &c., are narrow coastal plains of this type. These plains, when no longer maritime, are difficult to identify with certainty ; they were originally supposed to account for certain features in the older rocks, which may be explained in other ways.[1]

The largest plains, such as that facing the Arctic Ocean, cannot definitely be said to have been formed in any one way, either by grinding down or by building up. Probably the present slope of the surface is due to levelling action of rivers upon it ; this gives it also its seaward tilt. The material brought down by these rivers is, however, frequently piled up near their mouths, as is seen along the Baltic coast, and when warping also takes place the plain is gradually widened. These plains are peneplains, because the final shaping of the surface is due to river action, and therefore there is a seaward slope. A peneplain may, by uplift, be transformed into a plateau and then the rivers will begin all their activities afresh.

Inland plains usually form in the middle or lower portion of the basin of some large river, such as the Mississippi or Danube. They occur when the slope of the ground is slight and generally when the river is flowing over soft rock. The slope being so gentle, the river no longer flows over the obstacles in its path, but swings round them. Thus a serpentine course (fig. 68) is stamped upon the surface and, in such a course, the river flows more swiftly on the outside of the curve than on the inside. The curves thus formed are called ' meanders ',[2] and become more and more accentuated by the river slicing away its banks outside the curve and depositing material inside. Thus a wide level plain with high walls often marks part of a river's course, usually the lower

[1] See any book on Physical Geology for the ' Plain of marine denudation ' between the Silurian and Carboniferous rocks of Yorkshire.

[2] From the river in Phrygia.

part. The features of such a plain are beautifully seen in the plain of Hungary, in the valley of the Dee near Chester, in the Towey at Caermarthen (fig. 68), and in many other places. These meanders are commonest towards the river's mouth because the sea also helps to check the current, but when a river after traversing hard rock begins to flow over soft, the whole surface

Fig. 68. The Towey near Caermarthen, showing Meanders in Plain and high walls of Valley on either side.

is lowered rapidly, not only by the river and its tributaries being able to cut more deeply, but also owing to atmospheric denudation. The reduction of the slope naturally checks the velocity, so that in the end the river will tend to meander and to deposit material, thus forming a plain where soft rock occurs. In times of flood the water overflows a plain thus formed and deposits all over the surface a layer of silt ; the level stretch of land thus produced is called a flood-plain.

A river flowing through a lake is obliged to drop all the material it has brought so far in suspension, and all the smaller streams do the same. Thus, first a series of deltas and then a plain is produced by their combination. This is a lake-plain,

being formed by the partial or even complete silting up of a lake. Interlaken stands upon a lake-plain and Fluellen upon another, which is still forming at the head of the Lake of Lucerne where the Reuss enters. (For an example see fig. 69.)

Inland plains may be of very great fertility, as for instance those of the Ganges and the Po. The latter, flowing through the

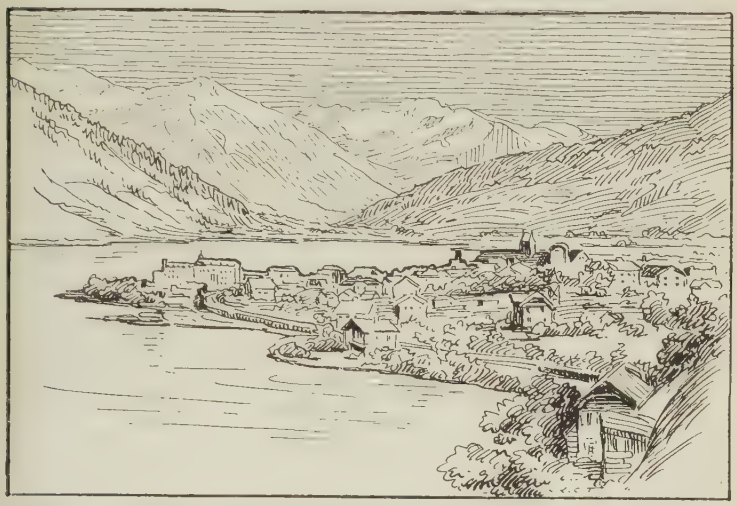


Fig. 69. Zell-am-See, built on the Delta of a Side-stream flowing into the Zeller-See, Austria.

plain of Lombardy, at a level rather higher than the plain itself, receives the accumulated material from countless torrents. By either natural or artificial flooding, the new material is repeatedly spread over the surface of the plain, which is thus constantly renewed and fertilized. Nothing more depressing could be seen in early spring than the wide expanses of water, interrupted only by stretches of mud and dotted all over with the little stiff brown mops of the pollarded mulberry trees, and yet in that dismal swamp the rice is already sprouting towards an ample harvest and one knows that the silk industry has contributed to the wealth of great cities. The vast Atlantic plains of N. America, again, supply in great part the granaries of the world, and the plain

of Hungary, on a smaller scale, produces some of the finest flour in Europe. The great central plain of Europe is partly of the character of an inland plain and consists of the coalesced basins of several rivers flowing northwestward. The inland part is fertile towards the west and centre, but on the east, where it widens out, climatic and other causes render it, in the main, unproductive.

Coastal plains have been more quickly settled and subjugated by man than any other type of land-area, but inland plains, in primitive times, were covered with vast impenetrable forests, which helped to impede drainage and so to retain swamps. For this reason, immense regions, such as the whole of Central Europe, were quite inaccessible and could only be brought into cultivation when clearings had been made.

Besides being accessible from the sea, plains favour internal communication, for roads can easily be made in any direction over their surface and no great difficulties impede the construction of railways.

*Plateaux.* The plateau regions of the world are either behind the plains, i. e. between them and the mountains, and then arising rather abruptly from the plains, as in the Eastern States ; or they may extend to the coast, where they end suddenly and steeply, as in Table Mountain and the south part of Western Australia. They differ from plains by being at a considerable height above sea-level and from mountains by having a broad and nearly level surface.

Plateaux, like plains, are generally formed of gently tilted strata, but, if original, i. e. not produced from plains by means of uplift, they consist of harder or more resisting material. Sometimes they are bounded by lines of fracture, indicating a former uplift.

If not original, they may be produced from plains in two ways :

i. When atmospheric agents, streams, and rivers have for a long time been at work in a mountain region, the whole surface is eventually levelled and is then called a plain of erosion ; such a plain is the Belgian coal-field. Frequently after this, the same area, by warping of the crust, is again uplifted and is then termed a plateau of erosion.

ii. It seems more often to happen that a plain of erosion, as

described above, sinks completely below sea-level and then after a long time is upraised again. During its submergence, marine sediments completely cover it so that, when uplifted, it has no longer an eroded surface. It is then called a plateau of accumulation. Plateaux of accumulation may also be formed in another way, i. e. by the outpouring of lava upon the surface, as for instance the Dekkan of India and the Snake River region of North America.

Vast plateaux occur towards the centres, sometimes extending towards the margins, of the continents of Asia, Africa and Australia. These regions, generally speaking, being remote or cut off from the sea, are liable to suffer from drought and often form deserts; in fact, most of the world's deserts are of the plateau type of relief. The greater part of the surface of these plateaux is gently undulating, their borders only being carved and fretted by streams. Owing to their dryness and the extremes of climate experienced in them, partly on account of their elevation and partly owing to their distance from the sea, plateaux, even if not actually desert, are seldom either fertile or thickly populated. An exception to this is the Dekkan of India, whose surface is covered with lava, which has at some time been poured out over it and still retains, in places, its ropy, twisted structure. This lava, having welled up from beneath, consists of minerals which have not had their valuable salts washed out by water and consequently gives rise to an extremely fertile soil, which supports a vast population with agriculture.

Plateaux are frequently dissected, i. e. cut into by the effects of the weather and streams; their original form can then be guessed at by the uniformity in height and appearance of the highest part of the country. A plateau of this kind forms the Yorkshire Moors, and each mountain is covered with a cap of what used to be a continuous sheet of hard material. A most striking example of a plateau of accumulation thus dissected is Saxon Switzerland, where the originally continuous surface has been carved out by water into all sorts of fantastic shapes (fig. 70).

Again, the basalt rocks of the Inner Hebrides and Antrim are isolated portions of a basalt plateau formerly of very wide extent.

Even the Scottish Highlands themselves are of plateau structure,[1] the heights being all about or just below 4,000 feet. The elevations here mark the presence of harder rock which, once deep below the surface, has become exposed by the softer upper layers being washed away. Through dissected plateaux we are carried on by imperceptible stages to mountains, for when the

FIG. 70. Dissected Plateau of Saxon Switzerland.

plateau is exceedingly lofty, as in the case of the Colorado region, a rift in it, such as the Grand Cañon, has walls of mountain height. These elevations, however, are really only topographic features of the third order, so, although they have the name, they should not have the full dignity of mountains proper.

One more case must be realized: when the plateau consisted

[1] See fig. 76, p. 202.

originally of tilted rock, as in England, east of a line from Dorset to East Yorkshire, the edges of the harder layers form escarpment hills or mountains. These may resemble block mountains superficially, but they are really different, being produced by denudation alone without faulting.

*Mountains*

Mountains and hills [1] differ from plateaux in being more or less isolated elevations, of which the sides converge upwards so that the summit is of limited extent. Mountains differ from hills in altitude and usually in profile. Mountains are above 1,000 ft. in height; their tops and part of their sides consist, typically, of bare rock, sometimes fretted into a sawlike outline, owing to the effects of weathering on the unprotected rock-face.

The actual shape of the mountain-top may be directly due:

1. To the geological structure, somewhat modified by ice-action, as is the case usually when we see needles, or pyramidal contours, e.g. the Tre Cime (Drei Zinnen), the forms of which are mainly determined by the stratification.

2. It may be the result of ice action. The Matterhorn, for instance, has a cusp-like profile, such as would be produced by three cwms, formed in a much earlier stage of erosion, now meeting; whereas the Breithorn is more rounded, as if ice had passed completely over it.

Hills are below 1,000 ft. in height and are generally clothed with vegetation. This protects their surface from the work of the weather so that their tops have a rounded form. Both hills and mountains may occur singly or in ranges or groups. A great mountain-group is called a 'massif'.

Mountains [2] are of two kinds:

1. They may be formed by elevation, or the building up of material. These have been called 'tectonic' mountains.

[1] The terms: mountain, hill, plain, &c., in a work of this kind, have to be used arbitrarily and not in the loose terminology of unscientific writing or of ordinary usage; thus the Nilgiri 'Hills' are mountains, being nearly 9,000 ft. in height, and the foot-hills of a high mountain range may be over 1,000 ft.

[2] Classification based on that of Professor James Geikie in his work on 'Mountains'.

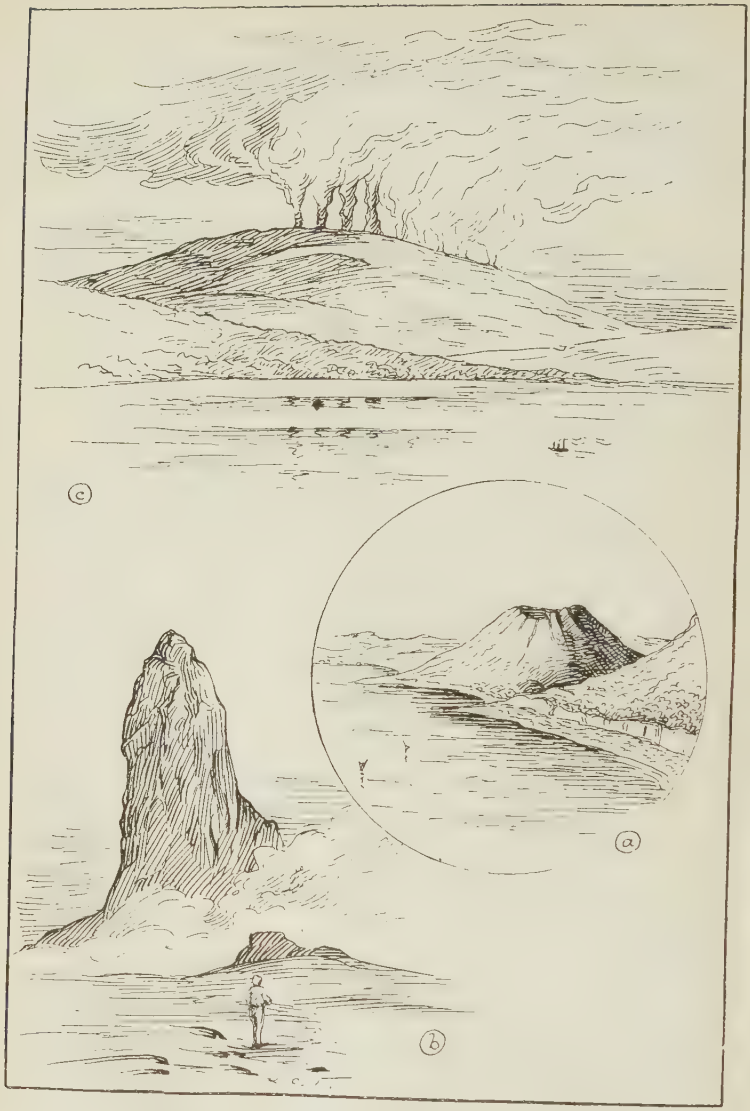



FIG. 71. Mountains of Accumulation: (*a*) entirely fragmental: Monte Nuovo (after Judd); (*b*) cone formed by viscous lava: Mont Pelée; (*c*) cone formed by liquid lava: Mauna Loa. Eruption of 1877, from a sketch by M. Ballieu, French Consul at Honolulu.

2. They are produced by the removal of surrounding material, when they have been termed 'subsequent or relict' mountains.

Tectonic mountains are built up in either of two ways :

i. They are due to superficial or nearly superficial action, i. e. to the piling up of materials on the surface : these are mountains of *accumulation* ; or

ii. to deep-seated subterranean action, which has resulted in the rupturing and folding of the earth's crust : these are mountains of *deformation.*

*Mountains of accumulation.* Tectonic mountains of accumulation are not of very great significance as they are more or less isolated from one another and of no great altitude. They are formed usually by volcanic action and are then produced in one of three ways :

(*a*) They may consist entirely of fragmental material such as cinders or ash ; for example, Monte Nuovo, which was built up 440 feet in a few days (see fig. 71, *a*).

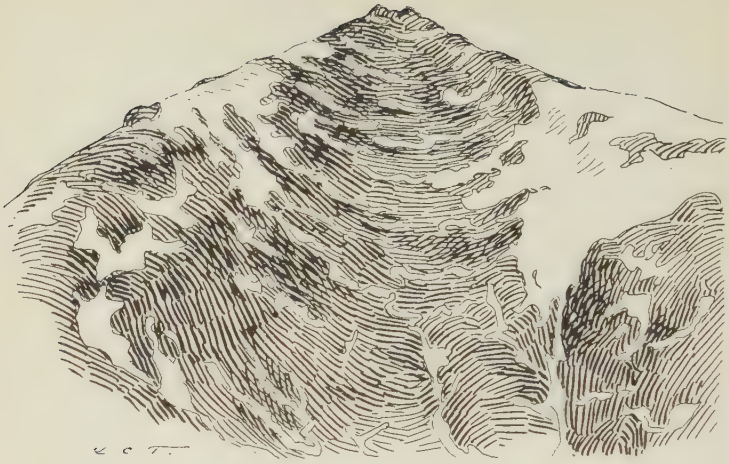
(*b*) They may be lava-cones, as the Puy de Dôme, and then are steep sided if the lava is viscous and gently sloping if it is liquid, as the spine of Mont Pelée in one case and the Hawaiian volcanoes in the other (see fig. 71, *b* and *c*).

The lavas or ash may belong to ancient geological formations, as in the case of Cader Idris, Snowdon, the Cuchullins (Skye), the mountains of the Lake District, &c.

(*c*) They may be formed both of fragmental material and lava, like the famous Fujiyama of Japan and Popocatapetl in the Andes.

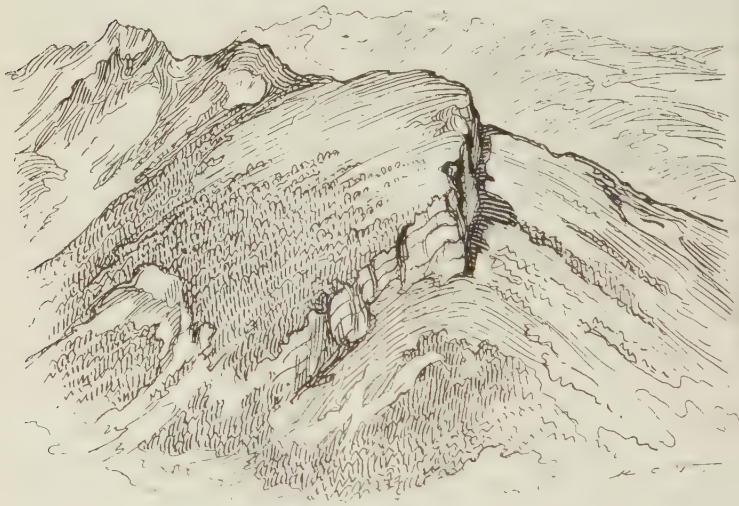
*Mountains of deformation.* Mountains of deformation are so called because the earth's crust has been either folded, broken or bent in their formation. They thus belong also to three distinct types.

(*a*) Fold mountains are produced by the earth's crust being thrown into waves. Gentle folds of this kind appear in the western Jura and the Appalachians : the former range being very young, geologically speaking, has its folds still showing as surface features (compare fig. 72 *b*) ; the latter has been worn



a.

FIG. 72 *a*. View of Snowdon with edges of synclinal folds outlined by snow. (After Salisbury.)



b.

FIG. 72 *b*. One of the Säntis Mountains formed by anticlinal fold.

down much more, so the concave parts, being the most stable, form the higher ground and the once elevated arches of rock are in the valleys. A good example in our own country of a synclinal fold forming a mountain is Snowdon. The drawing shows the edges of the folds outlined by snow (fig. 72 *a*).

In the Alps folding has occurred on a far grander scale and

Fig. 73. Early Stage in Formation of an overfold. Fold in the Schrattenkalk of the Säntis group.

the manner of it can be made out where the sides are bare. On the Lake of Lucerne, near Brunnen, the folds of rock wrap right round each other: near Schynige Platte one can see that the whole mountain-side only forms part of a giant fold. Wonderful examples of this folding can be seen in many places, notably on the way from Tre Croci to Cortina, where the contrasting colours suggest a resemblance to streaky bacon. When examined in detail, the Alps are found to consist of the most extraordinary contortions of rock, the folding having been first followed and

mapped by Professor Heim of Zurich, afterwards by Penck and others. The folding seems to have been caused by intense pressure, so that the strata which once covered a large surface are now crowded into less than a quarter of their original space. Shrinkage of the earth's crust on account of cooling is supposed to have caused this crushing and folding.

(*b*) Block mountains are produced when the rocks are actually broken, and may be due to the stretching of the crust in some parts caused by shrinkage in others. If we bend a piece of india-rubber or stiff clay into a curve, cracks appear on its surface. When the pressure that causes the bending is increased until actual fracture takes place, the material on one side of the fracture is usually left standing at a different level from that on the other. The earth's fractures so formed are called 'faults', and when such faults cause a block to be isolated from the rest, the block may be left standing high in the midst of a depression, as the peninsula of Korea, which stands out of the sea on each side.

FIG. 74. Section of Part of Rhine Valley to show formation of block mountains. (After Penck.)

These earth-blocks, called 'horsts' by Professor Suess, do not as a rule form high mountains. They occur also in East Africa and west and south-west of the Indian Ocean. Frequently they are formed by a fault on one side only. A well-known instance is that of the Vosges and Black Forest, with the trough of the River Rhine between them (fig. 74).

The Great Basin region of North America has been formed by a series of such fractures, which has caused the strata to take the form of a shattered arch.

(*c*) A third type of deformation mountain has originated through the bending up of strata, something in the manner of a blister, owing to the intrusion of molten matter below. When this is symmetrical, a dome-shaped elevation is formed. The structure was originally described by Gilbert as appearing in the mountains of Utah, and was called by him a 'laccolite', now

a laccolith. Of similar origin are sills and bosses or 'batholiths', as these are also produced by the intrusion of material. They, however, form a link between the tectonic and the residual type of mountain, as they may not have produced an elevation at first, but do so now, owing to the intruded material being much harder than the rest (fig. 75).

FIG. 75. Batholiths of Skye. Marsco, and another of the Red Hills in the foreground, show the massive cone-like or dome-like protrusions formed by a great acid batholith. The jagged Cuchullins in the background are carved out of a disintegrating gabbro boss.

*Residual or relict mountains.* Relict or residual mountains represent the other mode of mountain formation as opposed to the tectonic method. They have also been called mountains of circumdenudation. Such mountains are really topographic features of the third order as they are due to the dissection of a plateau, first by atmospheric weathering, later by the work of streams and rivers. Viewed from below, the side of the Colorado Cañon is of mountain build, for it forms a wall a mile high. If the area had been less rainless, regular mountains of this type would have been carved out. In the Scottish Highlands this work has proceeded very much further. The height of the original plateau is indicated by the mountain-tops, most of which have an elevation of 3,500 to 4,000 ft. The plateau was not of the

same material throughout, as in the Colorado region, but, after some denudation, hard granite bosses, which had been intruded into the softer rock, dotted the surface. These granite bosses have remained as the mountain-tops, and the rest of the plateau has been lowered to such an extent that the only indication of its former existence is the coincidence in height of the mountain-

Fig. 76. Dissected plateau of the Scottish Highlands.

tops. The plateau of Dartmoor is another good example of this differential action, and has been carved into long undulating ridges. Wherever the actual rock is exposed a tor is formed. The tors stand a little above the prevailing level and look like ruined masonry. This method of mountain formation is the most frequent, but the resulting mountains are less grand and imposing than those produced by folding.

*Topographic Features of the Second Order developed below Sea-level*

Topographic features of the second order are also developed below sea-level. They are :

1. Continental islands on the continental shelf ;
2. Ocean deeps, or hollows in the general sea-floor.

Continental islands fringe the shores of the land and are the

mountains or higher regions of the continental shelf, and are similar in structure to the neighbouring continents.

The ocean deeps are the abyssal regions of the sea-floor, which is otherwise only gently undulating and devoid of marked features. The ocean deeps are of fair extent with, usually, steeply sloping sides, and might be regarded as exceedingly

Fig. 77. Formation of needles near Chamonix.

elevated plateaux in reverse. Most of these occur rather near the line of chief elevation of the land, i. e. near one or other of the great world-ridges, for, as Professor Lapworth pointed out, the crest of the wave has its corresponding trough.

### *Topographic Features of the Third Order*

Topographic features of the third order, on the land, are due to the carving out and wearing down of mountains, plateaux, and plains. Beneath the ocean they are the oceanic islands, which are built up on the undulating surface of the sea-floor.

The chief features are the following :

Mountain summits, when worn away to sharp points, are called

needles or peaks. The elevated portions of plateaux, when dissected out so as to form prominences, but not worn away sufficiently to be termed mountains, are sometimes called buttes or mesas, according to their area (fig. 78). Buttes are steep-sided bastions like the Jail Rock, Nebraska. Mesas are broader, flat-topped, and tabular owing to the presence of a hard coping. These terms were introduced by American geologists, the former from the French, the latter word being Spanish. A 'kopje' is the South African name for a butte, and a 'Zeuge' or 'témoin' in the desert corresponds to a mesa. A gentle descent is a slope, and a steeply inclined surface is a cliff. If, however, the cliff is formed by the outcrop of layers of hard rock and is perpendicular or nearly so to the dip of the strata, it is an escarpment or scarp. An escarpment (fig. 79) can be distinguished from an ordinary sea-cliff by the fact that it is formed of one rock or one series of rocks and its top is nearly parallel with its base; e. g. the oolite escarpment of the Cotswolds, the chalk escarpment of the Chiltern Hills and North Downs. A cliff cuts through various strata or may be formed of unstratified material, and its top varies in height according to the hardness of the rock and the relief of the land behind it (fig. 80).

Fig. 78. Formation of buttes and mesas. Hance's Trail, Arizona.

The lower portions between the mountain heights are called 'cols' (fig. 81). The English word 'pass' is not quite synonymous, for a col is natural and a pass might be artificial; moreover, all cols would not necessarily be used as passes. An almost level surface, high up on the mountain-side, is an 'alp' and is used for pasturage in summer (fig. 109). When the mountain-side is deeply worn out in a circular manner by ice or the tributary

Fig. 79. Escarpment east of the Wye near Builth.

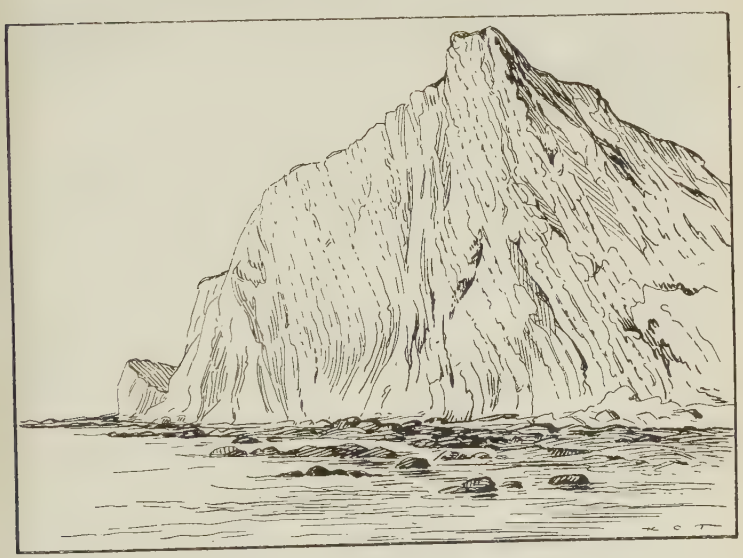


Fig. 80. View of Culver Cliff, near Sandown, Isle of Wight, wing strata nearly perpendicular.

streams of a river, or by both of these in succession, the resulting hollow is called a 'cirque'[1] (a 'corrie' in Scotland, a 'cwm' in Wales) (fig. 93). Below this, in the river's course, a long steep-sided channel worn out by a stream or river is called a 'gorge'[1] in Europe (fig. 94), a 'cañon' or a 'narrows' in America, according to its depth and the nature of its sides. Lower down the same

Fig. 81. Col de la Gueula, near Finhaut, Switzerland.
(From a photograph by Winifrid A. Jones.)

channel widens into a valley.[1] A valley, even if dry now, has always had a stream running through it. A rounded hollow without outlet, or with only a small outlet, is called a 'basin',[1] and a basin is often occupied by a lake. 'Terraces' may occur on mountain-sides or near rivers. In the former case they are caused by a projecting level surface of hard rock as on the Yorkshire hills. River-terraces[1] are patches of gravel at higher levels than the present stream-level, and have been left behind by the river as it cuts its way downwards. In them we sometimes find relics of ancient man, who dwelt beside the stream when it flowed at the higher level.

*Alluvial fan.* The half-cone-shaped deposit, left when a

[1] For more detailed account of all of these features, see below under 'Running Water' (pp. 216–228).

tributary stream with a steep slope enters the main stream, is called an alluvial fan or cone. This occurs most frequently in regions where the main valley has been excavated originally by ice. The side-streams have not had time to lower their beds to the level of that of the main valley and so approach it by hanging valleys and waterfalls, or they form alluvial cones owing to the sudden check.

Other terms which are used especially in connexion with glaciation will be defined when ice action is dealt with in detail.

*Oceanic islands.* As regards ocean features of the third order, it seems most logical to deal with oceanic islands under this heading, for the gentle undulations of the ocean-floor correspond to the mountains, plateaux, and plains of the land. Oceanic islands are not part of the normal floor, but are built up on this and owe their existence either to volcanic accumulation or to the activity of the coral polyp and other organisms, sometimes based upon a pre-existing volcanic elevation. These islands are in no way connected with any continent and have a restricted flora and fauna. The volcanic ones are particularly fertile for the same reason as the lava-covered plateau.

To the student of geography it may not at first sight seem clear that the features we now see are still in process of formation or destruction, nothing being permanent. They do really 'flow from form to form', only we are such short-lived creatures that to us most of the features have the air of permanency, 'as old as the hills' being a common expression to signify extreme permanence. Occasionally, as on the Norfolk coast, even in a lifetime rapid changes are recognized. The next chapter will deal with the nature of these changes and the agents that are producing them.

## XIX. Modelling of the Land Surface

### *Atmospheric Agents*

Having established, in the preceding chapter, the fact that land forms resolve themselves into certain well-marked types, although none of these can be said to be permanent, we must next proceed to study the causes and processes of their formation and demolition so as to obtain a clue to their present form.

*Summary of types of land forms.* To recapitulate, these types are as follows :

1. Mountains, i. e. greatly folded areas of comparatively new formation geologically, are of variable form, owing to their susceptibility to the action of denuding agents, e.g. the Alps and Himalayas.

ii. Plateaux : the ancient ones being the worn-down stumps or more or less levelled bases of an older series of similarly folded mountains, e.g. the Scandinavian plateau, or of shattered blocks, as in Great Basin region ; the newer ones consisting of comparatively undisturbed strata.

iii. Plains : older plains being former plateaux reduced almost to sea-level and newer plains consisting of parts of the Earth's surface that have almost or quite escaped folding.

iv. Subsidiary forms such as valleys and basins have also been mentioned, but the development of these being due to the modelling agents directly, a detailed account of the more important ones will be given below.

As seen above, except in the case of some volcanoes, hardly any mountain has been such all its life ; often it has begun as a portion of plateau or even as plain. In the same way, few plains have been plains always, some having formed parts of the sea-floor and others having been reduced from plateaux. The most important fact to realize in this connexion is then that, without tracing the changes constantly at work, we can understand but little of the true nature of scenery.

*The modelling agents.* The changes in the appearance of the Earth's surface, with which we are familiar, are produced by what we may call the modelling agents and consist in the removal of material from one part of the surface and its accumulation in another. The most important of these agents have commonly been called the agents of denudation, but, as the same forces which destroy in one part also rebuild in another, a more comprehensive term seems necessary. The two processes constantly going on are called denudation and deposition respectively, the latter being always consequent on the former.

*Classification of modelling agents.* The agents which carry on this twofold work submit to a rough classification into :

1. Atmospheric agents, as represented by heat and cold, frost, wind, rain and snow.
2. Fluviatile agents, consisting of streams and rivers, lakes and glaciers, and including also underground water.
3. Marine agents, due to the sea in its more active phases, as waves, tides, currents and marine ice.
4. Terrestrial agents due to the internal energy of the Earth, e. g. volcanic eruptions, geysers, earthquakes, &c.

The distribution of the influence of these agents follows certain general laws.

*Denudation of mountains.* High mountains, being bare of vegetation and much exposed, are subject to the influence of :

1. Sudden changes of temperature ;
2. Wind ;
3. Water in various forms :
   (*a*) As mist and rain ;
   (*b*) As frost, snow, and ice ;
   (*c*) As running water, somewhat lower down.

Thus the forms of high mountains are influenced mainly by atmospheric agents, but lower down they are affected by fluviatile agents. The amount of destruction done by changes of temperature in the high mountains is quite startling, e. g. one block of fallen rock in a Tyrolese valley was 100 ft. long ; the huge screes below the precipitous faces of the dolomites also bear evidence of this.[1]

*Denudation of plateaux and plains.* Plateaux and plains, being covered by vegetation except where the climate is arid, are subject chiefly to the action of rain and running water. In dry climates, however, they are influenced mainly by changes of temperature and wind. Thus, in plains and plateaux, the fluviatile agents are in the ascendancy. Only the margins of the land, whether mountain, plateau, or plain, are brought within the sphere of marine influence.

*Weathering.* The most universal sign of the work of the

[1] On the other hand, in more habitable parts of the Earth, where the scenery is tame, one violent thunderstorm will effect more denudation in thirty minutes than normal water action will produce in thirty years.

modelling agents is that which is called weathering. The combined effects of heat and cold, damp and drought, assisted often by wind, rain, and frost, produce in the rock-face this well-known result. Thus, heat causes the rock to expand and cold makes it contract, consequently the surface particles are loosened. These particles are either washed away by rain, rivers, or the sea, blown away by wind, carried away by glaciers, or they simply fall to a lower level, exposing a new surface.

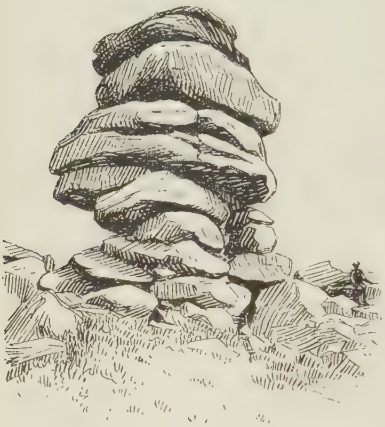


Fig. 82. The Cheesewring, near Liskeard, Cornwall.

Again, if rain penetrates into cracks in the rock, frost may cause the water to expand; it then acts like a wedge and splits the rock, thus furthering its decay. The processes of weathering brought to bear on rock which is unprotected by vegetation often produce fantastic forms, especially when sand is blown against the rock by wind. Good examples of these produced by blown sand are Brimham Rocks near Harrogate; whilst the Tors of Dartmoor, the Cheesewring of Cornwall (fig. 82), and many others are examples of similar forms produced by weathering along the joint-planes of granite. Where bare natural rock is not available, we can trace these same changes perfectly when the rock has been utilized for masonry. That the change here seen is due to atmospheric causes, is clear from the fact that the outside of an old church is much more worn than the inside, whereas a roofless ruin is seen to be worn inside and outside alike. In these cases even the rate of decay can often be gauged with considerable accuracy; for, though we cannot date the Sphinx, nor can we quite tell how much restoration of its outlines would be needed to probe the mystery of its facial expression, yet, in most buildings, the age and original form is known and thus the rate

of disintegration can be calculated. In Chester, several ancient buildings such as the old city walls, the Abbey Gateway, and St. John's ruins (fig. 83), are built of New Red Sandstone blocks which were obviously, at first, angular at their corners. An even more striking case is that of the old Abbey church at Shrewsbury, conspicuous from the railway. The blocks here resemble bolsters, the whole outer rim having been cut deeply back and rounded off.[1]

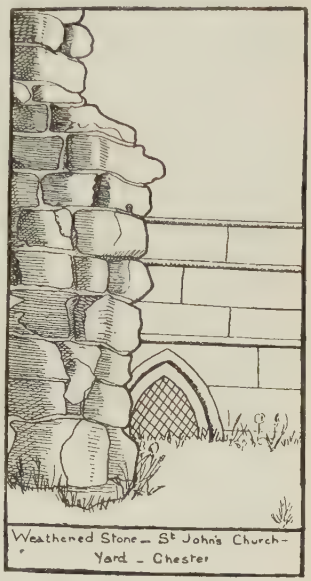



Fig. 83. Drawing of church ruins, *circa* fourteenth century, by Judith Welsby, Form Lower V, The Queen's High School, Chester.

It is difficult to distinguish the work of the various agents which combine forces in the act of weathering; that of rain and wind, however, has distinctive features.

*Rain.* The work of rain is seldom seen alone, but special cases of it stand out with remarkable emphasis. In Switzerland and the Tyrol, glaciers often leave behind them a characteristic soft, crumbly deposit, with large irregular blocks of rock scattered through it. Rain has had the effect of washing away this soft material, but wherever a block of rock occurs, it has protected the soft material immediately beneath it, so that the rain working round it has carved out a pillar, capped by the solid block. Such are the 'pyramides d'Enseigne' (fig. 84), one of which pillars is pierced by the road winding up from the Rhone valley to Evolena; such also are the famous earth-pillars near Bozen. Similar pillars have also been seen in Scotland, and are called 'demoiselles' in the United States.

*Wind.* In a temperate climate the destructive action of the

[1] Before or after a lesson on this subject the class should make drawings of the most striking examples of weathering to be seen in the town or country round. An old church will always serve as an object-lesson.

wind, like that of rain, cannot be separated from the work of the other atmospheric agents. In deserts, however, the work of wind is distinctive, for the surfaces exposed to sand-laden wind are covered with the finest possible polish; hence the obliteration of hieroglyphics on that part of Cleopatra's Needle which was not buried beneath the surface. Objects resting on

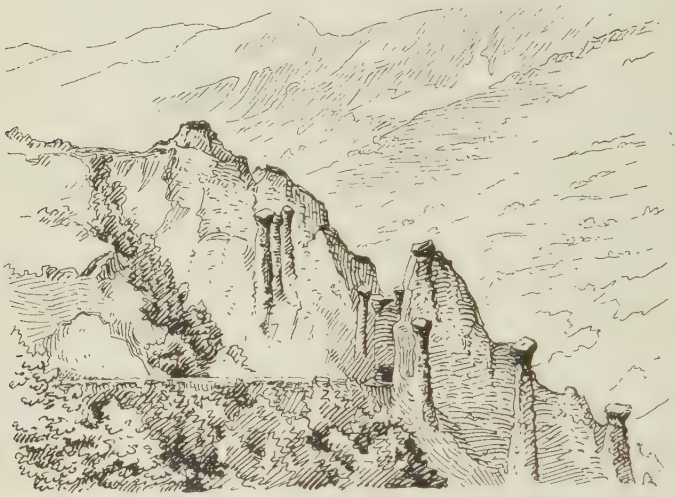


Fig. 84. Pyramides d'Enseigne, near Evolena, Switzerland. The high road passes through by means of a tunnel.

the surface are often undercut, e. g. stones on the desert floor. This is very noticeable in California, where stones are purposely piled at the bottom of telegraph posts, lest the posts themselves should suffer undercutting. During sand-storms, the sand is lifted by the wind and carried from one part to another, so much so that whole caravans have sometimes been overwhelmed by it.

The destructive work of the wind is seen not only in deserts but also along the shores of temperate regions. Here, if the soil is sandy, no protecting mantle of vegetation can form, and the prevailing wind being shoreward, the sand is blown up into crescentic heaps, called dunes. These sand dunes are magnificently displayed along the coasts of Wales, especially as one

passes in the train from Chester to Holyhead, and also beyond Swansea. They occur also on the southern Baltic coast and the west coast of Holland, France, and Denmark. On the east coast of the United States they extend for hundreds of miles, and near Cape Verde in Africa they are hundreds of feet high. Sand dunes are rarely still, but maintain a steady march inland, because the sand on the gentle windward slope is gradually pushed uphill and topples over and down the steep leeward slope. So relentless is this advance that villages have been smothered by the dunes, just as big cities have been engulfed by the sand of the desert. On the north coast of Denmark stands a little church tower alone in a wilderness of sand. The dunes, passing right over the body of the church, crushed it and drifted by (fig. 85). Of late years, societies 'for the reclaiming of the moors' have been set on foot, and a regular succession of cultivation has been planned. Tiny trees, planted on the windward slope, bind down the sand with their roots, and in course of time the surface becomes soil-covered and available for agriculture. Much land is thus being reclaimed. In the Landes of France a coarse grass, covering the dunes, binds the sand and affords pasturage for countless sheep. In north Jutland, near the Skaw, one magnificent series of dunes, the Raabjerg Mile (fig. 86), is being preserved as a national curiosity, so that its movements and other peculiarities may be kept under scientific observation. The exquisite tints on sea and land in this dune region have given rise to a little school of painters in that remote spot.

Fig. 85. View of the tower of the 'sanded-up' church near Skagen. (From a photograph by B. E. Clay.)

Dunes have characteristic shapes, akin to those of the ripples, which corrugate their surface. The form of a perfect dune produced by a constant wind is usually that of a crescent, with the convex side and gentle slope to the windward, the ends

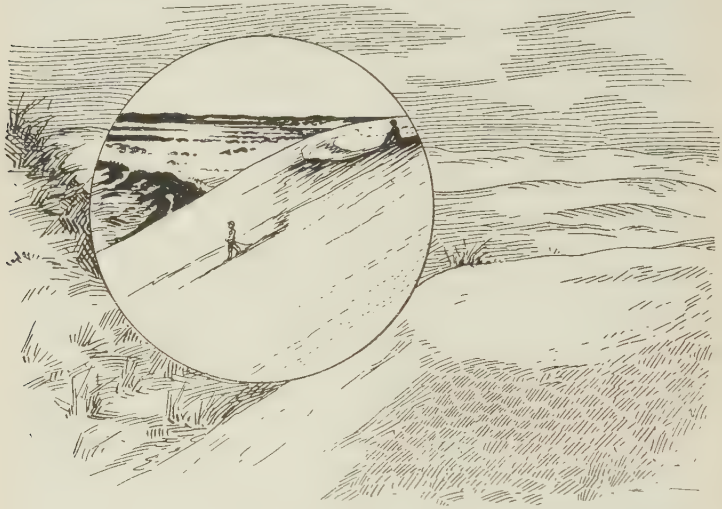


Fig. 86. View of Raabjerg Mile, near Skagen, Jutland. (From a photograph by C. L. Skeat.)

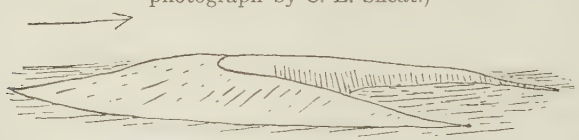


Fig. 87. Outline of a perfect dune (a Barkhan) formed by a constant wind. (After E. de Martonne.)

prolonging themselves like horns in the leeward direction (fig. 87). In a region where the wind is not uniform the dunes present a more irregularly corrugated surface. Often two or more dunes coalesce, forming a ridge perpendicular to the wind's direction. It has also been noticed that, in deserts, the larger dunes remain stationary, whereas the smaller ones move. This is due to the fact that the rarely falling rain is absorbed quickly by the sand, and the 'roots' of the larger dunes may remain slightly damp for a long time, so that they remain fixed.

Streams flowing towards the sea are often ponded back by the dunes, and form either freshwater or brackish lagoons or lakelets. In time, a lake of this sort becomes silted up and a marsh is produced, as in Swansea Bay, South Wales.[1]

When the wind does not blow inland, quantities of sand are blown out to sea, and form submarine deposits.

Another formation, probably due at least in part to wind, is of great importance because it produces vast surfaces available for cultivation. This is the loess, which forms all the fertile regions of Northern China, and causes its colour, yellow, to be the imperial colour. Many of the finest agricultural lands of the world, such as those near the Rhine, Danube, and Mississippi, are mainly loess.[2]

*Summary of work of atmospheric agents.* The influence of the atmospheric agents combined is of far greater extent than that of the other agents, for it affects the whole surface of the land, whereas the principal work of running water is confined to its own channels, and that of the sea to the land's margins only. Children on the way to school, if put on the track of discovery as regards weathering, will supply the most interesting data, and all sorts of evidence can be thus collected and tabulated. Much of the material worn off is simply moved from one place to another, and helps to form soil ; a great deal of it is collected by tiny streams, and in the end is carried to the sea by rivers. In mountainous regions and in the desert, where the rocks are bare, loose material is constantly being produced, and works its way downwards. The silence of the desert is punctuated by frequent loud reports, due to the splitting of the rocks, and the tinkle of fragments trickling down is almost continuous. In the mountains the peaks and ledges are perpetually being worn away. In the Dolomites the horizontal ledges are heaped with powdery stuff, which often looks like snow ; more often the screes consist of piles of angular rock-fragments, which rest on slopes, along valleys and at the foot of cliffs. Older mountains are

[1] Lord Avebury's *Scenery of England*, map on p. 143.

[2] A good map of the world-distribution of the loess may be seen in de Martonne's *Traité de géographie physique*, fig. 310.

recognizable from the fact that all splintery peaks and abrupt changes of contour have been worn away, in fact they are simply the stumps of their former selves, whereas young mountains, like the Alps, display these sharp outlines magnificently.[1]

The work performed on valley-sides by which a narrow U-shaped valley becomes V-shaped in cross-section, is also partly due to the atmospheric agents, but as their effect cannot in this case be separated from that of running water, it is best to consider it under that heading.

## XX. The Work of Running Water

### *Water (its Various Phases)*

Before dealing with the effect of running water in particular, it is as well to realize that the water which plays this part with such marked results is continually passing through different phases of existence. Thus, during a hot day, evaporation takes place from every water surface, small and great, the largest amount emanating naturally from the ocean surface. The vapour thus formed may appear as clouds, owing to condensation, and greater condensation causes these to form rain or snow. The snow remains long on the mountain-tops ; much evaporates, and much congeals into ice and seeks the valleys as glaciers. Some of the rain forms tiny rills, which converging, form streams. A great part of the rain is taken up by plants or animals and given out again as vapour ; some sinks into the ground, and may reappear on the surface in the form of springs, owing to change in the nature or arrangement of the rocks beneath. The smaller streams finally flow into the rivers, which convey large quantities of water to the sea and so complete the circle. A very small part of the water may never reappear at all, although geysers and perhaps also volcanoes give out some. It is believed that the fact of a small amount of water being

[1] Compare outlines of the Scottish Highlands (fig. 70) and view near Chamonix (fig. 77).

actually lost may, in the subsequent story of the Earth, bring about a condition of aridity similar to that of the planet Mars.

*Running water.* Of all the forms that water takes as a modelling agent, that of running water is most complex in its results, and gives a characteristic stamp to that part of the surface where it has been at work. It is also of profound importance as regulating

FIG. 88. A gully formed by a single shower. (After Salisbury.)

to a great extent the presence, amount, development, and maintenance of human life in any part of the globe. Every portion of the earth's surface, that is not submerged or arid, is brought under the influence of running water, and so potent are its effects sometimes as to revolutionize the surface completely.

*Cycle of erosion.* Running water is mainly responsible for what is called the cycle of erosion, and every portion of the earth's surface, that is not submerged, has arrived at some stage or other in this cycle. Thus, the mountain-top is shattered by frost and its particles, in time, usually enter the zone of influence of the streams. These streams, using the rock fragments as tools, score out gullies in the mountain-side (fig. 89); if the slope is steep

FIG. 89. Stream showing its partly used tools. Swilla Bottom near Ingleton, Yorkshire.

FIG. 90. View of young river. The Isar, in the Upper Isartal Bavarian Alps.

a little gully is sometimes carved out by a single shower (fig. 88). The irregularities of the surface and the instability of the drainage lines show that we have here an early stage in the cycle and the streams are said to be youthful, but a channel, once formed, tends to increase in size and depth. Lower down, the junction of many streams produces a river flowing in a well-defined and established channel (fig. 90). The vertical irregularities of the bed at this stage are more or less completely worn down, and the river flows along an even grade between walls whose height

Fig. 91. View of Tidenham bend on the Wye.

depends on the degree of maturity the river has reached, on the hardness of the rock over which the river flows, and on the rainfall.

Lower down still the river is larger in bulk, but has reduced its bed to a gentler slope, so that most of its eroding power is lost. It then lays down material along its sides and at its mouth, and is said to have attained senility; thus, normally, each stream progresses in maturity from source to mouth. If, however, an uplift subsequently occurs in some part of the river's bed, the result is rejuvenescence. Thus, the Herefordshire Wye greatly owes its beauty to an uplift in the region of the mouth, which has caused it, after producing beautiful curves, to incise them deeply into its rocky bed (fig. 91).

The behaviour of an individual river is not, as a rule, a very difficult study, especially as, in most towns, one is actually present and can be used as text. The description here of a typical river's course will serve to explain the number of minor features derived from the river itself, and may precede that of drainage areas, which is far more complicated.

*Course of typical river: mountain track (youth).* The place of

Fig. 92. The Saaser Visp emerging from the glacier at Saas-Fée.

origin of a river is called its source. When the country is still glaciated the river emerges from the base of the glacier (fig. 92) as a milky stream, as, for instance, the Rhone. The ice cave whence the Ganges emerges is called 'the cow's mouth'. When a river rises on a mountain of medium height the water is usually all rain-derived, the rain at first forming tiny trickles which tend, owing to irregularities in the surface, to flow together. The meeting of these streamlets soon produces a well-marked feature, shaped something like half a basin or a hollow cone. On the mountains in temperate regions these are very common, and are called 'corries' in Scotland and 'cwms' in Wales. It must be

borne in mind, however, that the extreme abruptness of the slopes of these particular corries and cwms is really due to ice action, as in Scotland and Wales the whole region has suffered glaciation. The Devil's Beef-tub (fig. 93), at the head of the Annan, near Solway Firth, is an excellent example of this, and its perils on a dark night are tellingly described in *Redgauntlet*. The road winding up past this marvellous hollow leads onward to the heads of the Clyde and Tweed, which rise in the same set of hills, but on the other side.

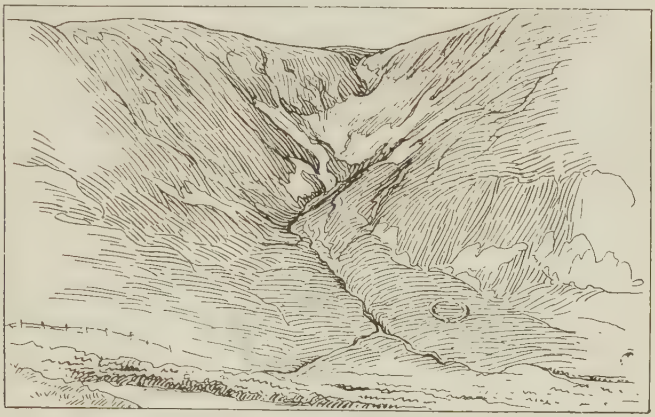


Fig. 93. The famous cirque or corrie at the source of the Annan, called the Devil's Beef-tub.

The streams which groove the sides of a corrie meet fanwise, and a single stream results. Sometimes the water at the base of the fan collects so rapidly that it has not time to flow off, or even more often, when the country has been glaciated, ice has helped to carve out a hollow. The work of ice can usually be recognized by the existence of a lip which marks the boundary of the corrie on the valley side. This process, assisted by others, which will be mentioned under 'Lakes', may result in the formation of a definite basin, often occupied by a lake. The frequent occurrence of this level surface or hollow causes many big rivers to appear to rise in lakes; the Upper Rhine, for instance, is only named after it issues from a lake, and the Adige

is hardly recognizable until it issues from the lake below Graun. In Wales large reservoirs have been constructed on this collecting ground of streams, these occupying the position which in nature has once been filled by a lake or bog, as for instance that of Lake Vyrnwy, which supplies Liverpool. Sometimes when the rain has sunk into the mountain-side the water, having reached impermeable rock, is forced to flow out again on the surface as a spring. This may occur at the head of the river's valley, or part way down the mountain slope. One of the sources of the Thames, the Churn, is thus spring-derived, the seven springs rising in a little pond, near which a rock bears the inscription :

HIC TUUS
O TAMESINE PATER
SEPTEMGEMINUS FONS.
T. S. E.

When the various streamlets have converged to form a single stream, or when this issues from a lake, it hurries downwards, overleaping all obstacles in its path, and thus producing falls. Often in this mountain track the stream finds a weakness in the rock, such as a joint, and flows along it ; then, its work being accelerated by and concentrated within the fissure, a gorge is formed (fig. 94).

Many gorges may be visited in Switzerland, hanging galleries and staircases having been built against their perpendicular sides. The deafening roar of the water gives some notion of its force, and this explains the extraordinary depth of the gorge.

*Valley-track* (*maturity*). On leaving its mountain track the stream, having a far greater volume than at first, erodes its bed rapidly, often producing a channel which may have high sides, and is called a valley.

Valleys are of two chief kinds, the one characterizing hard rock, limestone districts, or dry regions, and called a U-valley from the shape of its cross-section (fig. 95) ; the other being formed in softer rock, in regions where atmospheric agents are active,

becomes V-shaped in cross-section (fig. 96). The former occurs also in regions that have been recently glaciated, as ice leaves a steep-sided and flat-bottomed valley. The U-valley is well seen in the limestone regions of Yorkshire and Derbyshire; for instance, in the Dove, near Matlock. The perpendicular sides are here due to the vertical joints in the limestone rock, for water containing carbon dioxide dissolves limestone. Thus along these joints, which form planes of weakness, the water is doing a double work, both dissolving the rock and eroding it. A U-valley due to ice action upon a pre-existing river-valley is the well-known Lauterbrunnen Valley in Switzerland (fig. 95). The rounded shoulders or alps above the steep wall are the contours of the original water-formed valley. In reality both running water and ice are similar in their action, and leave perpendicular cliffs, but when the rock is relatively soft the valley sides become at once the prey of the atmosphere, which wears them away in such fashion that the valley becomes a wide V, instead of remaining U-shaped (fig. 96). Side-streams also assist in this, but practically the valley's *shape* is governed by the atmosphere, whereas its *direction* and *depth* are determined by running water.

Fig. 94. Gorge of the Fée (Feeschlucht), near Saas-Fée, Switzerland.

It is not beside the point to mention here the remarkable difference between the U- and V-valley with reference to man's occupation. From man's standpoint a U-valley is a mistake, for

FIG. 95. View of U-valley of Lauterbrunnen from Wengen. This shows also the rounded alps above the U and the hanging valleys on the right.

FIG. 96. (*a*) View of terraced and vine-cultivated slopes of the V-valley of the Douro ; (*b*) V-valley of the Mawddach, above Dolgelley.

the steep sides cannot be cultivated except where terraced at great expense, and its fissure-like form often keeps the sunlight from penetrating. In the Lauterbrunnen Valley, even in summer, the sun is not visible until about ten o'clock, and it leaves the valley soon after four. We notice that only one little town, Lauterbrunnen, stands *in* the valley, and that is at the entrance of it. The two residential places, Wengen and Mürren, are right above the valley, and have to be reached by mountain railways. Difficulty of access is another deterrent in U-valleys, the sides being unscalable in many parts, as in the Grand Cañon of the Colorado. A tiny village in Switzerland, Les Echelles, was so called because it was reached by ladders suspended against the rock face, and few but natives could mount them.

The slopes of the V-valley, on the other hand, being worn back and gently rounded by atmospheric agents, become quickly clothed with vegetation or can be easily cultivated. Villages and towns may spring up, even on the slopes and also at the base, for the sides are easily accessible, and the sun shines almost everywhere alike. The streams which flow into the main valley join the river at its own level instead of hurling themselves over from above. If the valley is a big one and the river is navigable, like the Rhine, towns arise along the stream at frequent intervals, especially where a side-stream, entering the main stream, makes a three-way means of intercommunication. Sometimes again, towns are built in terraces on the slopes of a similar valley, such as Lisbon, on the drowned valley of the Tagus. From the point of view of human occupation, river-valleys are very favourable, as the soil is generally fertile, the valley is sheltered, the slopes are well exposed to the sun, intercommunication either by land or river is possible, and water is easily obtainable.

Further work in the middle or valley-track is seen where the river is cutting its way into a plateau; when this has gone on for a long time, the plateau becomes entirely dissected as in the Central Plateau of France and the Scottish Highlands (fig. 97). In these cases we now call the salient points of the plateau 'mountains', because the valleys are so deeply incised. The plateau is often fretted out in such a manner that the numerous

and intricate waterways would resemble, if seen from above, the network of veins in a leaf.

The most characteristic feature of the lower part of a river's course is the flood-plain, which is formed of deposits made by the river in time of flood. It is sometimes bounded by a scarp on either side, and the river, when not in flood, traverses it

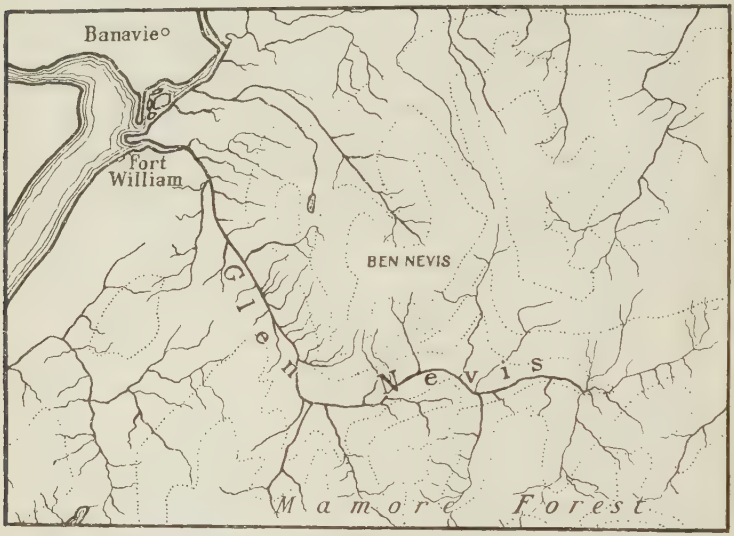



FIG. 97. Map showing small portion of deeply-dissected plateau of Scottish Highlands.

slowly towards the sea in a series of graceful curves. The flood-plain has a gentle tilt seawards, but as it is gradually being increased in extent on the seaward side by the deposition of material at the river mouth, the slope tends to decrease. The river on entering the plain carries its full load, but the slope being slight, the smallest obstacle causes it to swing round and to deposit material, instead of flowing over the obstruction. When a curve is once produced, the flow of the water is swiftest, and consequently the river's corrading power is greatest, on the concave side. The curve itself is thus accentuated, and the stream continues to undercut on the concave side, whilst on the convex side, owing to slack water, material is deposited (fig. 98).

If the conditions regulating the river's work persist during a long period of time, the curves will continue to increase in size and also to shift slightly down-stream, so that an almost continuous ridge sometimes results (fig. 98 *c*).

The curves are called meanders, from the river of that name

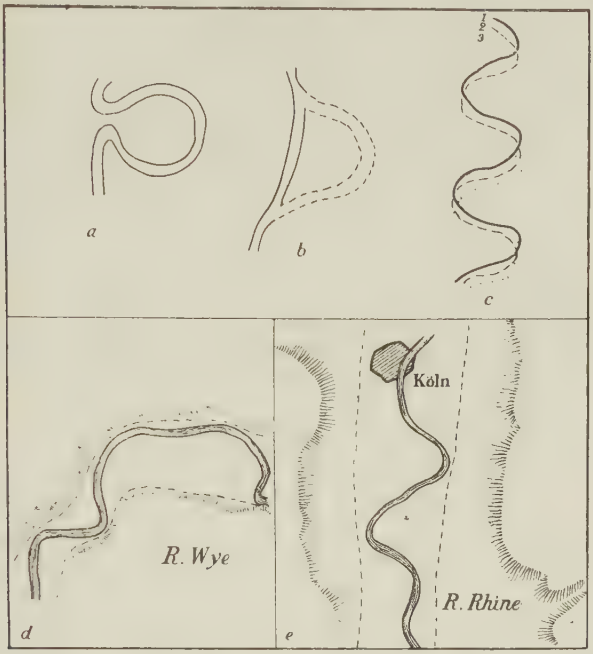



FIG. 98. The formation of meanders: (*a*) a curve becoming pinched out at the neck; (*b*) the river taking a short cut from one curve to the next; (*c*) the shifting of the curves down-stream (the numbers show three successive positions of the river); (*d*) the meander-belt coinciding with the flood-plain; (*e*) the meander-belt occupying the centre of the flood-plain only.

in Asia Minor, so the part of the river's bed over which it meanders is sometimes called the meander-belt, and a ridge forming the edge of this constitutes one kind of river-terrace. Sometimes the meander-belt winds right across the plain (fig. 98, *d*); at others it occupies the centre only (fig. 98, *e*), in which latter case the plain must have been formed under different conditions

from those now obtaining. The regularity of this process may be interrupted in two ways :

1. A curve may be pinched out at the neck (fig. 98, *a*), and this sometimes results in the formation of an oxbow lake.

2. The river may, if temporarily increased in volume, take a short cut from one curve to another. The outer bank of the portion thus deserted will also form a river terrace (fig. 98, *b*).

The broad flood-plain enclosed between the high scarps of the former river-bed is characteristically seen in the Vale of Clwyd, where the fertility of the plain is in striking contrast with the wild, unproductive uplands forming its rim. The Vale of Pickering is a more remarkable example as, owing to glacial interference, the river no longer flows down it at all, and yet the wide open fertile stretch has all the appearance of a typical flood-plain. The railway from Rillington to Pickering crosses the vale from side to side ; from Rillington to Malton it follows the southern rim of the valley, formed by the Yorkshire Wolds, whereas at Pickering it enters the region of the moors, which form the northern rim.

Wherever uplift has occurred in the course of a river, increasing the slope of the bed, the increased velocity results in downward erosion. The river then cuts through the flood-plain already formed, and strips of this may be left on either side as terraces. If the volume of the river is augmented in any way, the same effect may be produced. As in very early times man inhabited chiefly the river-valleys, valuable remains of primitive man have sometimes been found in the upper terraces, which mark the earlier stages of the river's development.

Much material is always carried by the river to its mouth, but when the river flows directly into the open ocean or into a part of the sea that contains strong currents, the actual mouth is kept clear, the material being swept away by currents and deposited elsewhere. Sometimes the material thus removed is deposited near the mouth, forming a bar, as at Conway, or a spit, as in Spurn Point, the immense elongation of which is due to currents running parallel with the coast. In other cases the material accumulates some distance out at sea and produces sand-banks, such as those in the Wash, which are carefully charted.

The sand-banks in the Bristol Channel sometimes show a reddish colouring through the water when the tide is flowing out ; boats cannot pass up the channel without a pilot, on their account.

When, owing to the sinking of the land, the river widens considerably before reaching the sea, an estuary is formed (fig. 99). Some rivers flow out between rocky walls, and the mouth, which then gradually widens and deepens seaward, is called a 'ria'. Good examples of rias occur in the south-west of Ireland, but the name is Spanish.

When the river, after widening seaward between its rocky walls, narrows again and then passes into another and wider

Fig. 99. Estuary of Fowey River, Cornwall. This estuary is a very busy one, especially owing to the export thence of china-clay from St. Austell's.

opening over a shallow lip, the structure is technically called a fiord (fig. 100), although the term fiord is sometimes applied to river mouths without this peculiarity, which is ascribed to ice action. Many cases of this occur in Scotland, where the river mouth is called a loch.

If the material brought down is deposited at the river's mouth owing to absence of currents, as happens when the river flows into an inland sea or lake, the mouth gets gradually silted up. This is very well shown in the Wash, which is being converted into bog on its landward side by the activity of four rivers, the Witham, the Welland, the Nen, and the Ouse, many interesting plants being found on the new land thus forming. Another example is seen at the head of Loch Long, Scotland. Several

of the West of England rivers are also filling up their mouths. In the old days the packet boat for Ireland started from Parkgate on the Dee estuary, but now, in spite of the 'new cut', the estuary is hardly navigable. The Mersey estuary also has a bar, and cannot always be entered by the big liners, although dredging operations go on continually. The Barmouth estuary has more than a mile's width of dry sand at low water (fig. 101), and the Dovey also exposes huge banks of sand.

Where material is deposited so rapidly as to cause the river to divide into several smaller streams or distributaries, a tri-

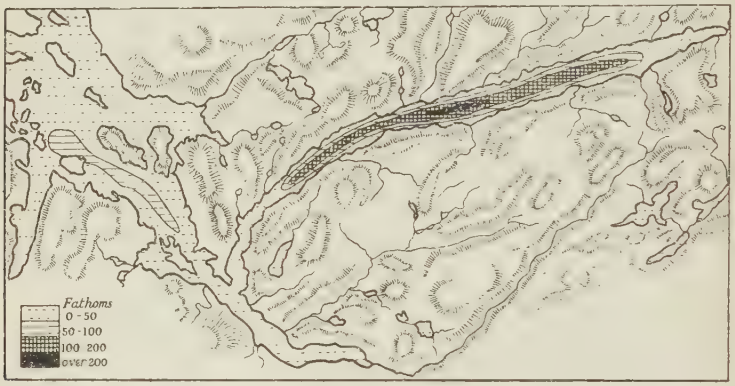



FIG. 100. Map of Stavanger Fiord and Lyse Fiord, showing deeper water in centre and shallower water over the lip.

angular platform results. This is called, from its shape, a delta, and as the surface soil is undergoing perpetual renewal it is extremely fertile. Deltas are found usually in gulfs or inland seas or lakes. The best examples are the delta of the Mississippi on which New Orleans stands, jutting out into the Gulf of Mexico, and Lower Egypt, 'the gift of the Nile'.

*Types of drainage areas.* From the consideration of a typical river we have been able to touch on the topographical forms which owe their existence entirely or in part to rivers or to moving water in some form or other. If we are confronted by a map of a well-watered district (fig. 97), the various streams and rills seem to fret the surface almost as effectually as the veins cut up the substance of a leaf, and it is not easy to realize

that these apparent intricacies can be unravelled and the whole explained in terms of a simple underlying scheme.

This idea of evolving a simple scheme and then working out its possible complications was first adopted by the American writer, I. C. Russell, and his terminology has been accepted. Much work has subsequently been carried out by W. M. Davis and others.

*Simple drainage area.* The best plan is to take an imaginary simple case (as actual cases of the kind are few and far between)

Fig. 101. Estuary of Mawddach, near Barmouth, silted up with sand. The shores have well-marked ice-worn features. (From a photograph by B. E. Clay.)

and to work out the probable variations afterwards. The simplest plan of drainage is that which would be found on a piece of land recently upraised from beneath the sea. Elevation being due to deformation of the crust, the land would take the form of an arch or anticline, and, in the case of an arch, rain falling on this would produce more or less parallel streams from the crest downwards. The effect of the streams will be to wear the surface into channels with ridges between, and also, in time, to alter its curve, owing to the different work done by a stream in its upper, middle, and lower track. Where the stream is small, it carries away little material, even though it is swift. In the middle of its course it is still rapid, and is also much

larger, having been met by tributary streams, therefore it removes more material. Lower down it is larger still, and has acquired its full load; it therefore has little or no power for downward erosion, and frequently deposits material, giving only a gentle slope to its bed. Thus an arch or ridge which began by being evenly convex owing to folding, after stream erosion, is bi-concave in profile. The curve of each side is called the curve of water erosion and its very beautiful outline is of constant occurrence in temperate regions. When the streams can remove no more, the base level of erosion is reached. The curve then remains the same unless a new uplift occurs and gives the stream new energy with which to begin its work all over again. The steep and picturesque banks of the Wye are believed to have been produced in this way (fig. 91).

*Complications due to heterogeneous nature of material.* So far the matter is fairly simple, and it would probably remain so if the rocks on which the streams work were of uniform hardness, for then both main and side streams would carry on their work evenly. Thus, supposing the accompanying sketch (fig. 102, *c*) shows the work of main and side streams on the even slope of a surface sloping in the direction of the arrow, the whole part within the dotted line will be at a lower level than the rest, and the side-stream high up in the valley ($s^1$) will be altogether on a higher level than that lower down ($s^3$). If the original arch or ridge was composed of rocks of unequal hardness, directly the outer layer is cut through complications will arise.

Fig. 102, *a*, shows an arch or anticline consisting of a series of rocks, the upper part of which has been removed by denudation, so that rocks of unequal hardness are exposed, giving the surface a 'grained' structure (fig. 102, *b*). Such an uplift having occurred, a number of streams would be initiated, flowing from the crest downwards and thus across the grain. These streams, because they depend directly on the dip of the rocks, are called consequent streams (fig. 102, *c*, $c^1$ $c^2$), and their tributaries, which are formed later, are called subsequent (*s*).

Fig. 102, *c*, shows two consequent streams flowing side by side, each with tributaries. If the surface of the rock is homogeneous,

i. e. if the outer surface of the arch has not yet been cut through, there is nothing specially to determine the position of the tributaries, so they may or may not arise opposite one another. If the surface consists of hard and soft rocks alternately, the tributaries tend to flow in the softer rock, as that is cut away more quickly than the hard, and water always seeks the lowest level. For this reason the tributaries are more or less nearly opposite one another.

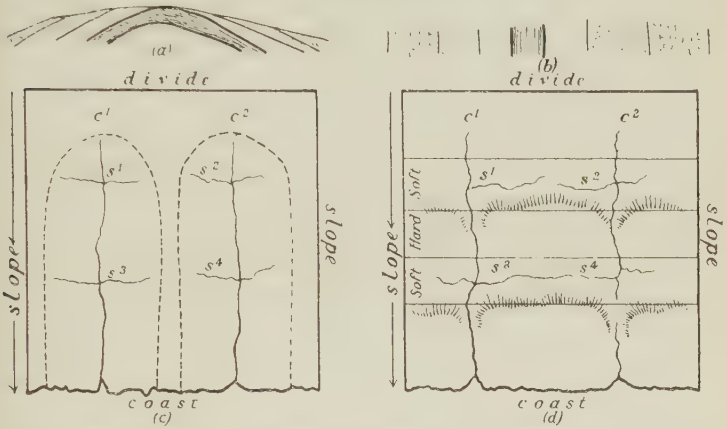



Fig. 102. Phases of stream development: (*a*) an anticline, or arch, consisting of rocks of unequal hardness; (*b*) surface view of the same, showing 'grained' structure; (*c*) consequent streams flowing over a homogeneous surface, or first stage of stream development on a 'grained' surface; (*d*) later stages of stream development on a 'grained' surface.
*c*, consequent stream. *s*, subsequent stream.

Fig. 102, *d*, shows a further stage in stream development. It is seldom the case that the consequent streams are of quite equal importance. If, for some reason, $c^1$ is a stronger stream than $c^2$, it will cut its way down more quickly, so that $s^1$ and $s^3$ will erode more, and so lengthen their courses more rapidly than $s^2$ and $s^4$. Then either $s^1$ or $s^3$, or both, will soon cut their way through the subsidiary ridge between the consequent streams, thus uniting with a tributary of the consequent stream $c^2$ on the opposite side of the ridge. The subsequent stream thus formed, flowing at right angles, or nearly so, to the original consequent, will still continue to lower its bed

rapidly, so that of the adjacent consequent $c^2$ will also be lowered at the place where they join. In time the main stream will break in two; its upper waters will flow into the subsequent stream $s^3$ originally belonging to $c^1$, while the rest continues its way to the sea, having literally 'lost its head'. When the valley of the subsequent river thus formed has been further reduced by subaerial denudation, the hard rock will tend to stand out as a landward-facing escarpment, notched where the consequent stream flows or formerly flowed. Streams flowing down the face of the escarpment are known as obsequent; in the same category is included a small part of the lower waters of the original consequent stream, which is often obliged to flow backwards, and into what was its tributary (fig. 102, *d*).

The above description indicates the first beginnings of what finally becomes a highly complicated network.

*Complications due to ridge of unequal height.* Other minor complications are introduced in various ways. If a ridge or divide is of uneven height in different parts, a stream flowing from a higher part of the ridge collects more water and deepens its bed more rapidly than those which arise at a lower level. Its tributaries, also deepening their channels more rapidly, may capture all the upper waters of one or more of the other rivers on the same slope.

*Complications due to ridge of unequal slope.* If the ridge is not symmetrical, but steeper one side than the other, the rivers of the gentle slope collect more water, but those of the steep slope have more power, and consequently erode more rapidly, so that the watershed or divide becomes shifted in the direction of the gentle slope.[1]

*Actual examples of complex drainage.* The beginnings of a complication of this kind are shown on the opposite sides of the Pennine Range. We know that the rainfall on the west side is more copious than on the east; this fact may have helped the rivers on the west to deepen and strengthen their original consequent channels. On the east, also, a whole series of consequent

[1] An example of this is described by W. M. Davis, *Geographical Essays* (Ginn & Co.), p. 602.

streams, consisting of the Swale, the Ure, the Nidd, the Wharfe, and the Aire, descends from the Pennine Range, and it seems natural to suppose that these rivers flowed out separately into the sea like those of the west. However, the rock traversed by these streams on their way to the sea was alternately soft and hard; they must have flowed first across the soft rock of the Vale of York and then across the harder material of the Wolds. The result has been that they were all captured in succession by a subsequent stream now called the Ouse, and their waters are all together conveyed by it into the Humber. This is a simple case of river capture.

Another good example of a subsequent stream capturing several consequents is the North Tyne, which receives consequent streams on its western side, and on the other side has captured the head-waters of the Wansbeck and Blyth.

*A river basin a geographical unit.* Just as a continent consists of two or more main slopes, each of which, by means of the sub-aerial and fluviatile agents, is brought into direct relationship with the adjacent ocean, so, through the same agents, each of these oceanic slopes has become roughly partitioned into river basins. One river basin is distinguished from another by the fact that practically every drop of water finding its way into it by precipitation, if not evaporated into the atmosphere, is carried into the sea by the main stream, to whose existence that particular river basin is due, and for this reason the whole area is called the 'catchment area'. The entire conditions of the area are dominated by the river; its amount and swiftness determine the fertility of the basin, its navigability and direction the positions of human dwellings, its general features the possible occupations and activities of its inhabitants, even their mental outlook is affected by its aesthetic appeal. The realization of the river basin as a definite geographical unit was one of the steps that marked the advance from the old system of teaching by memory work to the new, which demands mental effort on the part of the pupils themselves. As soon as this method began to supersede the old one of teaching rivers in one list and towns in another, the dry bones began to live. For this reason it has become the

custom of late years to devote almost too much detailed study to the work of rivers and denudation generally, rather at the expense of other portions of the subject. This work has, however, had a most stimulating effect on the general study of geography, and has established its position on a sound scientific basis.

## XXI. The Work of Frost, Snow, and Ice

The work of water when below freezing-point is partly that of an atmospheric agent and partly fluviatile; it also has distinctive features of its own, but is, on the whole, best considered here. The actual work thus performed cannot be very well studied in regions of extreme glaciation, because there a mantle of snow and ice protects the Earth's surface from direct attack. Round the coasts of Arctic and Antarctic lands, where a less rigorous climate obtains than in the centre, and also in high mountain regions, the action of snow, frost, and ice, however, is manifest; it can also be traced in regions no longer glaciated, but which have formerly been ice-covered, as in the northern continental regions of the northern hemisphere.

The work of snow is mainly protective, as, wherever it rests, the actual surface of the land does not suffer disintegration. If the ground is level or gently sloping, and precipitation is in excess of evaporation, snow remains and forms nevés or snow-fields which, though protective in themselves, act as gathering-grounds for glaciers. During the storms of winter, in the late spring, and early summer, the snow itself becomes an agent of destruction. Great masses, becoming detached, fall from the heights and completely bury everything beneath them. Hence the necessity for avalanche galleries on the Alpine roads and railways, in spite of which many a traveller has lost his life, traffic has been stopped, or disastrous floods caused. On a hot summer's day the thud of the avalanches falling from the Jungfrau massif resembles rounds of artillery-fire.

A very important kind of work, which has been ascribed also to snow and ice, is the formation of the 'cwm', 'corrie', or 'cirque'. The snow-drifts, resting on a steep serrated slope,

afford a constant supply of water for the work of frost below each drift, and thus a series of couloirs or channels is cut in the face of the slope. The stages of cwm formation were recognized and described by Ferrar in the northern face of Discovery Bluff in Antarctica. The snow in each drift becomes congealed into ice below the surface and, melting taking place at its upper edge, the work is further assisted by the water thus derived, which trickles down between the ice and rock.

FIG. 103. View of battlement peaks of Tre Cime (Drei Zinnen), near Lake Misurina, Tirol.

The ice-slab thus eats into the hill,[1] and in course of time a half-funnel-shaped cavity or hollow is produced. These cwms are highly characteristic features of former glaciation throughout northern Europe, and may be ascribed to the combined effect of snow and frost in a region where glaciation is no longer at its maximum.

The effect of frost alone depends on the amount of melting that can go on during the day. Water sinking into the cracks of the rocks freezes and expands, thus acting like a wedge in forcing the sides apart. The result is to accentuate the rock's own structure, by hewing it out along its joints or natural lines

[1] Mr. W. D. Johnson, an American geologist, had himself lowered into the space between the ice and rock-slope in the Sierra Nevada so as to observe this process in operation.

of division. When the cracks are vertical or nearly so, splintery peaks are produced, like those of the ironically styled Tanzbödeli (little dancing-floor),[1] or we get block-like masses such as the 'Drei Zinnen' (fig. 103) or crystal-like forms such as Monte Cristallo. Fragments of all sizes and shapes, becoming detached by means of frost, roll down the mountain-sides. These, on meeting with an obstacle, such as a change of level or the side of a glacier, may be piled up to form screes, which have the shape of half-cones, the outer slope being at the angle of rest for fragmental material. If not piled up, the fragments are often dragged along by the glacier or become frozen into it. The subsequent fate of such fragments will be mentioned under 'Glaciers'.

The direct work of ice, considered apart from that of frost and alternate freezing and thawing, differs in method and amount according to the nature of the ice-body. Thus, there are two kinds of land-ice which can perform work on a large scale: the ice-sheet or continental glacier—as it is sometimes called—and the glacier, distinguished from the above mentioned as the mountain-glacier.

The ice-sheet will be more fully described in the chapter dealing with the cold dry desert, of which it is the characteristic feature; the mountain-glacier, in its most familiar form of the Alpine type, differs from this through being confined to a valley. It has a distinct, sometimes steep, slope, and in this resembles a river, but differs in being largest at its source and narrowing towards its tip, which is convex, like a tongue (fig. 104). The glacier has its origin in the fields of snow, congealed beneath into ice, which rest in the hollows of the mountains; it flows for long distances down a steep-walled valley, ending abruptly at some distance below the snow-line. The movement of a glacier cannot be detected by the unaided eye, but can be easily seen by fastening a row of stakes or flags across it from side to side. The movement is found to be greatest in the centre and on the surface, where there is least friction. Along the edges of the glacier, and sometimes forming a crescent-shaped mass at its foot, are the moraines, consisting of fragmental material which, denuded from

[1] See fig. 109, below.

the mountains above, often rolls down the slopes of the valley until arrested by the ice. Moraines may also be medial (fig. 106), when two or more ice-streams have joined. Emerging at the base of the glacier is a stream, often milk-white in colour owing to suspended sediment. This stream collects its waters partly

Fig. 104. View of Franz Josef Glacier, showing its convex tip narrowing like a tongue. (From a photograph by M. F. Skeat.)

from tributaries which flow down between the valley-wall and the ice, partly from water trickling down crevasses, and partly from the melting of the surface (fig. 108). Besides the moraines, the glacier's surface is strewn with rock fragments of all sizes, shapes, and kinds, derived from the mountains above. When these are large enough to protect the ice surface beneath them from the sun, they become supported on pinnacles of ice and look like

huge mushrooms growing on the glacier. Most glaciers are traversed by crevasses, except when the floor is very even, as in one of the glaciers at Arolla, or if their floor has almost no slope, like the Ebene glacier in Austria. Crevasses may be of very great depth and, being sometimes partly concealed by a cornice or bridge of opaque re-frozen snow, they are often very dangerous. By looking down into their depths or by creeping in under the glacier where it sags away from the valley-side, the clear delphinium blue of the ice can be seen. The

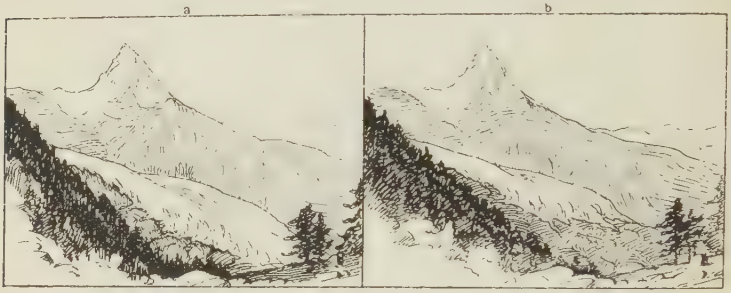



Fig. 105. (*a*) View of one of the Matterhorn glaciers, from a photograph taken near Zermatt about forty-five years ago. (*b*) Sketch to give some idea of the same glacier at the present day.

Alpine glacier of fifty or more years ago was a far more impressive and beautiful sight than its too often shrunken and somewhat dingy representative of to-day (see fig. 105, *a* and *b*). The Findelen glacier, for instance, which now hangs far above the Zermatt valley, was then seen entering a field of corn. This is the result of the last receding hemicycle of glaciation, during which milder climatic conditions have prevailed and consequently evaporation has exceeded precipitation.

The work of ice-sheet and glacier differs in that the one seems to move from the centre outwards, but where there is no downward slope its movement is often inappreciable, whereas the other has very varied but quite appreciable rates of motion. It is not possible, in a region of former glaciation, always to attribute the work definitely to the one or the other, but the ice-sheet certainly did the crushing and disseminating of material

on a broad scale, whereas the glacier, with the assistance of its water-stream beneath, actually scooped out the floor of the valleys, originally water-worn.

It will be simplest to deal first with the kinds of work that are common to ice-sheet and glacier alike, and then to mention those that seem distinctive of the one or the other.

The glacier and the ice-sheet—the latter at any rate near its margins—do not consist of ice only, as great quantities of material are either embedded in the ice or are carried as passengers upon it. The embedding process is assisted by huge cracks in the ice, called crevasses, which are formed wherever the ice flows over an uneven surface. The effect on the ice of the convexities in a valley-floor can be illustrated by bending an old piece of india-rubber over the finger. It is seen that cracks form at right angles to the convexity. If the surface is convex both ways, there are two sets of cracks, at right angles to one another, and a kind of pinnacle of ice, called a 'sérac', is produced. The rock material is thus buried at all depths and a good deal must project on the under surface or sole of the glacier, as it has such a remarkable rasping effect on the valley-floor.

In the Gletscher Garten at Lucerne the forsaken bed of a former glacier can be observed: this shows many of the results of ice sculpture in a most striking manner. These, speaking generally, are:

1. The scratching and polishing[1] of the rocky floor in the direction of flow of the glacier.

2. The sculpturing of the floor, wherever an unevenness occurs, into a curious hummocky shape, with its long axis parallel to the glacier's direction, the surface of the hummock being smooth on the side facing up the valley and rough on that facing down the valley. These hummocky shapes are called 'roches moutonnées'[1] from their resemblance to the backs of a flock of sheep. The dissimilarities of the two sides are due to the glacier's direction of flow; the smooth side has been polished by the ice forcing its way uphill over it, and the rough has had its irregularities protected with the material dragged over it by the

[1] These are illustrated below, figs. 110, 111.

ice. A good deal of 'plucking' is done by the glacier when fragments project, and it thus provides itself with more tools for its future work.

3. Formation of moraines.[1] These heaps of fragmental material are derived either from the screes, which pile up against the glacier's side, or from the pieces smashed off projecting spurs by the glacier's relentless onward march. Edging the glacier on either side, they are called lateral moraines; but, when two glaciers meet, the contiguous lateral moraines become a medial one. Sometimes several ice-streams join; we then get the effect of dark lines on the surface, resembling ruts in a carriage drive, as seen on the great Aletsch glacier (fig. 106). Terminal moraines are more or less crescentic in shape, owing to the convexity of the glacier's tip. Moraines on the great ice-sheet of Antarctica stream outwards from the projecting rocks, in the direction of flow of the ice.

FIG. 106. Moraines of Aletsch glacier resembling ruts on a carriage drive. Märjelen See in foreground. (From a photograph by Winifrid A. Jones.)

4. Boulders, or erratic blocks,[1] have been transported great distances by ice and are identified as being of a totally different material from the rock on which they rest. They are often found in a position of unstable equilibrium, just as they were deposited by the melting ice.

[1] These are illustrated below, figs. 112, 113.

5. Deposits of so-called drift and boulder-clay are the surest indication of ice action. The ice in melting has left vast areas covered by these formations. Glacial drift can be recognized by the rock fragment being often more or less angular and not in the least sorted into sizes, as is the case in river deposits.

6. Icebergs are the broken-off ends of glaciers and therefore consist of land-ice. When the glacier reaches the sea, as may happen in lands within the Arctic or Antarctic Circles, the movement of the ice is checked, and also, ice being lighter than water,

FIG. 107. View of upper part of Franz Josef glacier, showing projecting rocks. (From a photograph by B. E. Clay.)

it is bent up so that cracks form, causing large blocks of ice to become detached. These gradually float away, carrying with them their load, which consists partly of rocks resting on the surface and partly of fragments frozen into the substance of the ice. The rock fragments have been derived from the land in various ways, some having been rent from the mountain-tops or sides by frost, and others conveyed to the glacier by streams flowing down tributary valleys. All contribute to form the iceberg's load and, on the melting of the ice in warmer water, the whole heterogeneous mass drops to the bottom of the sea. A glacier thus acts as an agent of deposition as well as of denudation.

The grandest work performed by glaciers is the scooping out of valleys and the rock-basins of lakes. The glacier begins by

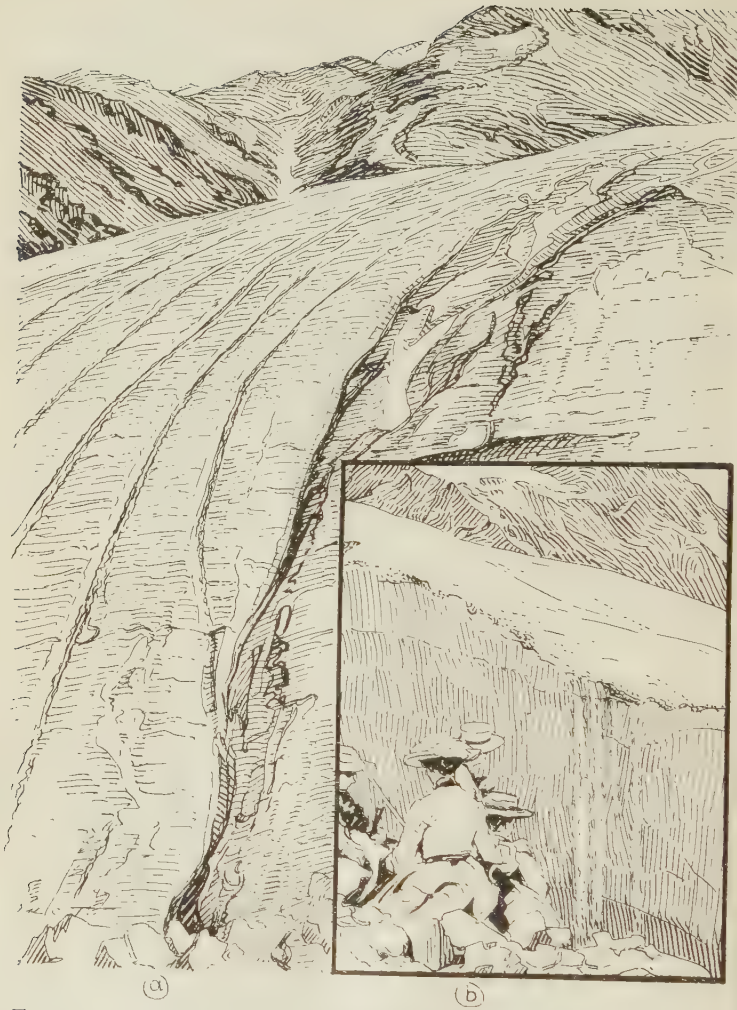



FIG. 108. The surface water of a glacier: (*a*) The Morteratsch glacier, showing surface scored with little runnels of water: (*b*) Side of Ferpècle glacier, showing water trickling down between the ice-wall and the moraine to join the stream underneath. (From photographs by M. F. and C. L. Skeat.)

flowing down a pre-existing valley, formed by a stream during a previous mild period; the higher slopes of this valley, remaining above the trough of the later one, form the alps or mountain pastures so characteristic of Switzerland. The glacier, having once established itself, remodels the whole. The trough is U-shaped in cross-section, with a floor often rather step-like, the steps, however, sloping slightly backwards. When the edges of these project upwards so as to form barriers across the valley, they are called 'riegels'. The side valleys seldom meet the main valley at its present level, as their streams are unable to keep pace with the great body of ice, so they appear suspended above the main valley and are therefore called 'hanging valleys' (fig. 95). Projecting masses of rock sometimes occur in the valleys, the ice-stream having at first passed over them and then, at a later stage, parted and swept round them (fig. 107). The ice of the glacier is assisted in its work by water, which trickles over the surface (fig. 108, *a*) and down between the rock-wall and the ice at the glacier's side (fig. 108, *b*), and then flows beneath it, emerging as a stream where the glacier ends (fig. 92). The water can often be heard, though not seen, as it rushes along beneath the ice.

A splendid example of a valley thus formed, but later forsaken by the ice, is the Lauterbrunnen valley (figs. 95, 109). Looking up it, we see the broad trough of the alps in the part of the valley above the direct influence of the glacier and the steep wall of the present glacier-worn valley below. The Staubbach on the right leaps from the cliff and spreads like a veil over its rocky face, and many other hanging valleys are seen along the same side. Wengen occupies one alp and the mountain railway to Mürren passes over the other. The jagged frost-carved peaks of the Tanzbödeli stand out against the Breithorn, which heads the valley.

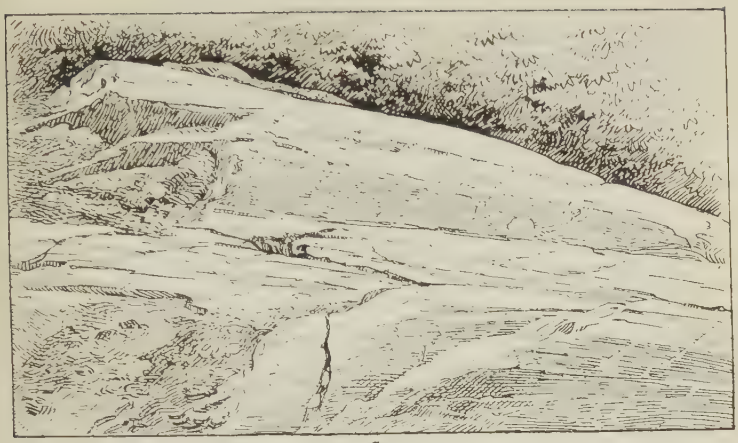
The backwards-sloping step-like ledges formed by ice on a valley-floor, when excavated by the sub-glacial stream, may become the rock-basins of small lakes. If these succeed one another, like the beads on a chain, they are called Pater-noster

lakes. These sometimes occur together with moraine-dammed lakes, but being rock-basins must be distinguished from them (see under ' Lake basins').

The work of ice has a special interest for us in that so much of the finest scenery of the British Isles has been left us as a legacy by it. The great ice-sheet, with its attendant glaciers, was just finishing its work of modelling the face of a great part

Fig. 109. View of Lauterbrunnen Valley from the Leiterhorn, showing ice-formed valley with alps and hanging valleys on each side, also the Tanzbödeli in the middle distance. (From a photograph by E. G. Skeat.)

of the northern hemisphere about or soon after the time that man was leaving the first traces of his existence on the face of the globe. The Ice Age, as it was called, had its times of waxing and waning glaciation, but the ice seems never to have extended beyond a line drawn across Central Europe and passing along the Thames. In spite of the time that has elapsed since the withdrawal of the ice and the constant wear and fret of the agents that then took on the work, the ice features still play a conspicuous part and are so striking that they at once arrest



*a*

*b*

FIG. 110. Comparison between glaciated forms occurring in Britain and in regions still glaciated : (*a*) a glaciated rock surface near Bowness, Windermere ; (*b*) the same occurring in the Gletscher Garten, Lucerne.

the eye accustomed only to tamer views and more gently flowing outlines.[1] The features had been long noticed by British geologists, who had, however, failed to account for them, until the great naturalist Agassiz, fresh from the mountains of his native land, ascribed them to their true origin.

FIG. 111. The same as fig. 110, continued: (*a*) Roche moutonnée of Nant Ffrancon Valley, North Wales, compared with (*b*) the same occurring in Chamonix Valley. (From photographs by E. G. Woods and C. L. Skeat.)

The work of the ice in the British Isles is best studied in the English Lake District and in the Scottish and Welsh mountains, where it has often had considerable effect on the forms of mountains and hills. Further evidence abounds, as for instance the wonderful cwms or corries, of which 'The Devil's Beef-tub' (fig. 93) is only one among many. A glaciated surface is seen occurring near Bowness, Lake Windermere (fig. 110, *a*), exactly like that seen in the Gletscher Garten, Lucerne (fig. 110, *b*). The roche moutonnée of Nant Ffrancon (fig. 111, *a*) compares with that of the Chamonix Valley (fig. 111, *b*); the moraines of Lake Ogwen or Wrynose Pass (fig. 112, *a*) and of La Grande Casse in Savoy (fig. 112, *b*) have the characteristic hummocky form which is so easily recognized; the perched block in Borrowdale called the

[1] Though ice contours are often very much rounded they do not flow into one another like the usual outlines of non-glaciated regions. The outlines of limestone districts must be considered exceptional, as the soluble nature of the rock causes the valleys to be U-shaped. The ice features strike the eye of the initiated at once. A pupil of the writer's, cycling for the first time in Wales, cried out with surprise and delight as one familiar form after another appeared.

Bowder-stone (fig. 113, *a*), like the one near Salvan, Chamonix Valley (fig. 113, *b*), rests in a precarious position. Even the direction of flow of the ice can be traced, as in the case of the Shap granite which, with its characteristic large crystals of pink felspar, is picked up all over Yorkshire and can be recognized on many a cottage window-sill. Similarly, fragments of rhomb-

FIG. 112. The same as fig. 110, continued: (*a*) moraines of Wrynose Pass between Lancashire and Yorkshire; (*b*) moraines of La Grande Casse in Savoy.

porphyry from Christiania fiord are found throughout East Anglia; the present writer acquired a handsome piece from the beach at Cromer. The so-called drift, a glacial deposit which covers so much of the surface of the country north of the Thames, took its name from the general belief that it had been carried by floating ice when the face of the land was sea-covered. The extraordinary contortions in the drift of the Cromer coast are, however, much more easily explained by the land-ice theory, which is now more generally held. We seem, in

the Cromer cliff, to see the floor, which was traversed by the great ice-sheet in its relentless course, as it went crushing like Juggernaut's car over great and small alike, licking up some fragments and smashing others, grinding many to powder and making an inextricable medley of every kind of rock, so that pieces of all shapes and sizes lay finally huddled together and caught up in its fantastic folds.

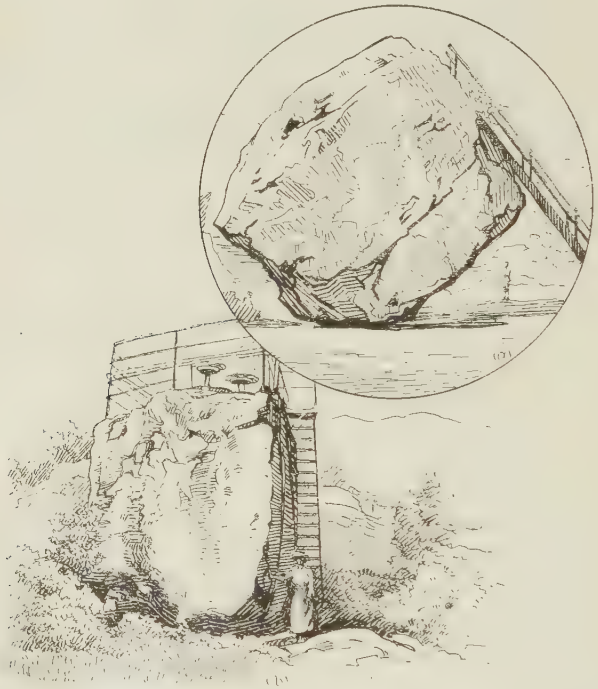


FIG. 113. The same as fig. 110, continued: (*a*) the Bowder-stone of Borrowdale; (*b*) Rocher du Berger, near Salvan (from a photograph by C. L. Skeat).

# XXII. Lake Basins and Springs

*Lake basins.* More or less connected with rivers and their work are lake basins, which must be treated next. The formation of lake basins has been a matter of considerable controversy among geologists because it was at first believed, as Ramsay suggested, that most lakes were lying in hollows in the rock which had been scooped out mainly by ice. Subsequent work has proved that lakes owe their origin to various causes, of which ice erosion is perhaps the most insignificant. Professor Marr, in his book *The Scientific Study of Scenery*, deals with this subject in such a manner that it is only necessary here to refer the reader to that book and to give a brief summary of his statements. Professor Marr enumerates four ways in which the hollow, called a lake basin, may be produced :

1. By the accumulation of loose material to form a barrier or dam.
2. By differential movement of the Earth's crust, to some aspects of which the word ' warping ' has been applied in America.
3. By volcanic action, forming craters.
4. By erosion.

1. *Accumulation of loose material forming a barrier.* The barrier may consist of various materials derived in different ways :

(*a*) *Barrier of ice or caused by ice.* In the Märjelen See the barrier is the ice of the glacier itself ;[1] other dams due to ice agency are those of morainic matter or glacial drift. Moraine-dammed lakes are formed in Westmorland and lakes in the hollows of glacial drift are common, where the surface has been recently covered by an ice-sheet, as in Finland ; some of the Cheshire meres are believed to have the same origin.

(*b*) *Barrier due to landslip.* Landslips forming a sudden barrier will produce a lake by ponding back a river ; a lake was thus

[1] See fig. 106.

formed near Sion in Switzerland in 1749. Lac Lauvitel, near Le Bourg-d'Oisans in Dauphiné, was produced by an enormous landslip, through which its waters now escape by three underground streams. These streams emerge on the surface 125 yards below the lake.

(*c*) *River-formed barriers.* River-formed dams are of various kinds. Sometimes a side-stream, suddenly checked in the main valley, deposits a fan of débris which gradually builds itself across that valley; an alluvial delta of this kind has divided Lakes Brienz and Thun, producing the platform on which Interlaken stands. Again, many rivers raise their banks during time of flood, thus forming flood-plains. Tributary streams are then sometimes prevented from joining the main stream, as in the case of the Murray River in Australia, quoted by Gregory.[1]

Or, again, a third kind of river dam arises in the meanders of some rivers as they wander on the last part of their journey towards the sea. Material is perforce deposited on the convex side of the curve owing to the checking of the current. Sometimes, owing to rain in the upper reaches, the volume of the river is increased. It then abandons its meander and cuts a straight channel across the loop. The resulting crescent-shaped piece of water is called an oxbow lake along the Mississippi, a billabong in Australia, and a cut-off in our own parlance (fig. 98, *b*).

(*d*) *Barrier formed by river meeting sea.* The co-operation between a river and the sea causes a bar to form sometimes at the river mouth, and this, in time, ponds back the water as a lagoon or lake, as seen in the case of the Fleet, behind the Chesil Beach (fig. 119). The Broads of Norfolk, now freshwater lakes, are believed to have been, originally, shallow valleys which, during a period of slow submergence, were converted into wide estuaries. When submergence ceased, a spit of sand, due to the current from the north, extended gradually across the mouth, converting each estuary into a string of irregular lakes, partitioned by the sediment accruing from the side-streams, which material the small and sluggish rivers were quite unable to remove. Thus the spit of sand at the river mouth was the prime

[1] See *Geography, Structural, Physical, and Comparative.*

factor in the formation of Broads, although there were several other contributory causes. Similar lakes are found also in deltas, such as the Mississippi delta. Several small rivers, as well as the Po and Adige, contribute the material of the storm-beach, called the Lido, at Venice, which, making an incomplete barrier across the bay, walls in the lagoon. Storm-beaches raised by blown sand reach a considerable height, but they may be burst through, as in the case of the invasion of Holland by the sea, which resulted in the Zuyder Zee.

(*e*) *Lava-formed barrier.* One other method is known by which a flow of the river may suffer arrest and a lake be formed, namely, that in which lava happens to cross the valley. The lava on cooling forms an impenetrable wall and the waters are held up above it. Examples are known in Auvergne and in Italy.

Thus, whatever the material may be and however derived, it tends to have the same result, i. e. the creation of a barrier across the valley of a stream or river.

2. *Differential movements of Earth's crust.* The process referred to by Professor Marr as differential movement of the Earth's crust, or warping, has produced most of the larger lakes, those, namely, of the Aralo-Caspian depression, those of the interior of Africa—the Dead Sea perhaps may be included in the same movement—and those of the Great Basin Region of North America. The lakes of Switzerland and northern Italy are probably mainly traceable to this cause, although the formation of barriers and dams has had some part in them. Small instances of differential movement, due not to warping, but to solution of underground material, are seen in the 'Sinkages' of Cheshire and other places where the rock is partly soluble.

3. *Crater lakes.* Crater lakes are usually small and simple in origin, as the hollow resulting from a volcanic outburst or from accumulation of fragmental volcanic matter will naturally become filled with rain, if it is not porous. Examples occur in the Eifel and Auvergne; also near Naples.

4. *Lake basins formed by erosion. 'Rock-basins.'* Some lakes are formed by erosion, in which case the agent directly concerned

is ice. As the glacier or ice-sheet passes over the rock surface, it is supposed that a certain amount of material can be actually scooped out by the rocks frozen into its sole, or 'moraine profonde', which may have a rasping action. This removal of material takes place more readily if the surface of the rock is already weathered. The 'rock-basins' thus formed can be distinguished from moraine-dammed lakes by the fact that the

FIG. 114. Glaslyn, the outlet of which has been carefully examined. It appears to lie in a true 'rock-basin'.

water is enclosed by a rim of solid rock. Lake Glaslyn, beneath the steep face of Snowdon, is believed to have been formed in this way (fig. 114).[1]

*Underground water.* Connected both with atmospheric and fluviatile agents is underground water, the active manifestation of which is seen in springs. As explained above, rain becomes distributed in various ways, and that which is not evaporated back into the atmosphere, does not find its way into the substance of plants, and does not form streams and rivers sinks

[1] See Jehu, T. J., 'Bathymetrical and Geological Study of Lakes of Snowdonia and East Carnarvonshire', *Trans. Roy. Soc. of Edinburgh*, 1902, p. 463.

into the ground. This also is variously disposed of, some reaching the surface again in the form of springs and some sinking deep into the earth. Whether this last partly finds its way to the surface again, through the agency of volcanoes, is a point lately under discussion.

Springs (fig. 115) are important as assisting in the formation of rivers; they also have a marked effect on human occupation. Their origin may be explained somewhat as follows: rain, sinking through porous rock, often meets with non-porous rock, through which it cannot pass. The porous rock becomes saturated up to a certain level[1] like a sponge, so that water flows out at the surface anywhere below that level, especially at the junction with the non-porous rock, and thus a spring is formed. A geological fault, i. e. a break in the rock, often has the effect of bringing porous rock and non-porous rock up against each other, and the resulting springs are sometimes of great assistance in geological mapping, as marking the line of fault.

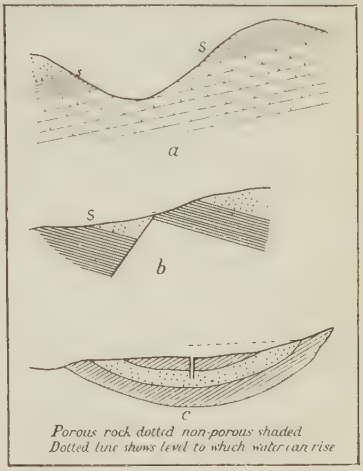



Fig. 115. Formation of springs: (*a*) Springs due to arrangement of strata; (*b*) Spring due to geological fault; (*c*) Artesian well. (*s*) = position of spring.

Fig. 115, *a*, is a case in which springs are due simply to the arrangement of the strata one upon another; *b* shows a spring caused by a geological fault. In *c*, where porous strata are imprisoned between two beds of non-porous rock, if the upper non-porous layer is bored through, the water will rise to the same level as the outcrop of the non-porous beds. This is an artificially produced spring and is called an artesian well, from the name of the province of Artois, where it was first introduced.

[1] Known as the level of saturation or water-table.

Thermal springs are most common near regions of volcanic activity and have always been associated with them in the human mind. It was, in fact, believed, until recently, that the explosive force of a volcanic outburst was due to pressure produced by the generation of steam, and that the column resembling steam, so clearly seen when Vesuvius is in eruption, was actually due to water. Recent researches seem to show that there is some doubt whether steam actually issues from the volcano, but, at any rate in regions which are, or have been, subjected to volcanic activity, hot springs exist. The heat is probably due partly to their issuing from great depths and partly to weakness in the Earth's crust, which admits of chemical changes generating heat. The temperature is often extremely high : in New Zealand the heat is sufficient for cooking purposes ; even at Bath the water issues so hot that a cat sometimes sits warming itself upon the pipe at some distance from the spring. Thermal springs also frequently contain, in solution, minerals which are considered beneficial for various human ailments, and for this reason they often form the centre of a considerable population and are a source of wealth to the country in which they occur.

*Uses of springs.* The geographical importance of springs is (1) that they supply fresh water and hence tend to attract population. This is seen especially in the oases of the hot dry desert. (2) They increase the volume of rivers. (3) They also sometimes have thermal or mineral properties which are considered to be curative of certain diseases, and in this way may affect the concentration of population in a remarkable degree.

## XXIII. The Work of the Sea

*Marine action of denudation and deposition.* The work of the sea, like that of the other modelling agents, is twofold, that is, it aids both denudation and deposition. In the former case its activities are limited to the margins of the land ; in the latter case it sorts land-derived material into sizes and spreads it far and wide over its floor, as far from land, indeed, as the finest material can remain in suspension.

Denudation, on the part of the sea, is carried on by waves, tides and currents. In ordinary waves, as explained above, the water has an oscillatory motion and the wave as a whole does not travel; breakers, however, advance upon the land, and, when reinforced by high tides, can compass considerable destruction in a comparatively short time. During a storm the wave pressure alone has been found to amount to over three tons on a square foot. Where the coast is rocky also, the rock fragments

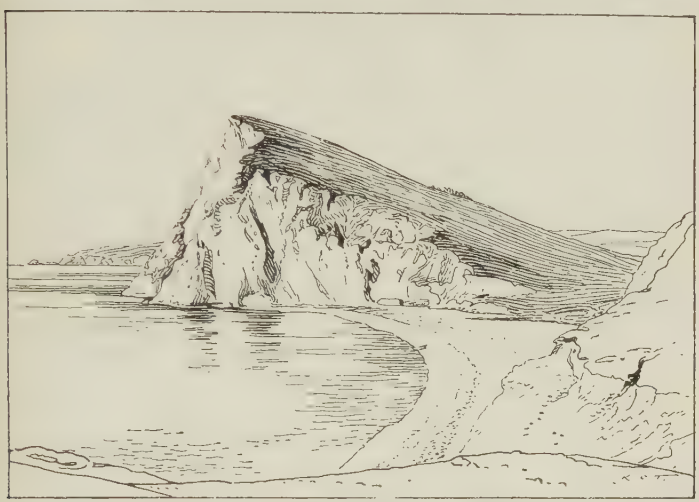


Fig. 116. View of St. Alban's Head, showing that the seaward half of the drainage system has been removed. This accounts for inland slope.

which become detached serve as artillery and are hurled against the coast. Not only this, but hard rocks are traversed by cracks due to joints and bedding-planes. The sea advancing, compresses the air in these cracks, and this acting as a wedge, accelerates the rock's disintegration.

*Formation of cliffs.* The work of the sea on hard rock usually produces a bold outline, for all loose particles are removed either by the waves or by wind and rain. Thus, round the whole margin of the land, the hard rocks look as if part of them had been roughly removed by a saw; in the case of Shakespeare's

Cliff and St. Alban's Head (fig. 116) clearly the seaward limb of a small drainage system has been entirely removed, for otherwise it would be difficult to account for the landward slope.

The form of a cliff is usually determined by joints and stratification planes, which form lines of weakness. On the north coast of Anglesey, where the joints are vertical, the sea, working along them, has produced wonderful gullies, on whose vertical walls grow the tiny plants which seek out such sheltered spots, so that one looks down through a delicate fringe of green to the dark water far below.

*Formation of sea-caves.* Sometimes where a stratum of soft rock occurs, or where a main joint is present, the sea will bore its way in, undermining the cliff and forming a cave. The floor of such a cave is often washed nearly level but with a seaward slope, whereas the roof depends on the direction of joints and bedding planes. In the old days these sea-caves were the haunts of bands of smugglers.

*Formation of 'blow-holes'.* In South Wales and in Ireland remarkable chimney-like shafts have been produced by the compression of air in the crevices. These 'blow-holes' may be some little distance inland, and yet, leaning above them, one can hear the swirl of the waters deep below and feel the breath of the sea.

*Formation of 'stacks' and 'needles'.* A line of weakness occurring across a promontory and parallel to the coast enables the sea to carve out an arch, like the arch in Freshwater Bay. Supposing after a time the roof of an arch falls in, we get Stack Rocks, such as those of Pembrokeshire, or the Needles of the Isle of Wight. On the other hand, these may have been formed by a whole promontory being cut through vertically, as was the case with the Old Man of Hoy, Caithness, and the remarkable outline of the worm, or dragon, at Worm's Head (fig. 117).

Thus, the denuding effect of the sea on hard rock, assisted by the atmosphere, produces scenery, the features varying according to the nature of the rock.

*Inroads made by the sea.* In soft rock its actual effects are often greater, but far less noticeable, except in the case of soft crumbly cliffs like those of the Norfolk coast. Here the mystery and

horror of a landslip due to undermining by the sea is thrillingly described by Watts-Dunton in his novel *Aylwin*. At Sidestrand, picturesquely called 'Poppyland', a great part of the old churchyard has been washed away and the deserted church itself almost hangs over the edge. That of Reculvers, in Kent, a noted landmark, would have been removed by the sea long ago if a sea-wall had not been built. When the shores are low-lying and composed of friable material such as sand, the sea often makes serious inroads. The most striking instance of this is the Zuyder Zee,

FIG. 117. View of Worm's Head, near Swansea, showing the head, body, and part of the tail of the worm, or dragon.

which was formed by a series of inundations in the thirteenth century, during which it was computed that about 80,000 people lost their lives. Similar catastrophes have affected Holland on various occasions, also the coasts of Denmark.

*Formation of coves and bays and fretted outlines.* Owing to alternations of hard rock and soft, the sea's action on the coast is often differential and produces beautiful curves. Thus the coast of Dorset is fretted into a number of pretty little inlets, the harder rocks standing out as headlands. One of these coves, that of Lulworth, is so rock-girt that its basin is calm even in rough weather, and so deep that the Weymouth steamer runs right

inshore, enabling the passengers to alight by a plank bridge. Along this coast, marine action has not proceeded far, for after a time, the currents being checked in these hollows, denudation ceases and the concavities become silted up. Thus the final result is a splendid sweeping curve with hard rocks forming the salient points as in Cardigan Bay.[1] It must not be assumed, however, that all bays are due to alternations of hard and soft rock; indeed, it is dangerous, without much evidence, to believe that any are produced by this means only. Probably Cardigan Bay and many others of the kind result in part from the foundering of a land-area, by means of which the low ground becomes covered by the sea and the high ground projects as promontories, even when not formed of harder rocks than those of the bays.[2] It is a well-known fact that the land's margin is never stable; in some parts even considerable warping has gone on. In the present state of our knowledge of coast-lines it is often impossible to say how much of the outline should be ascribed to erosion and how much to Earth movement; it is clear, however, that the harder rocks project and the soft tend to recede. The differential action of the sea on rocks is beautifully shown around the shores of Pembrokeshire. Comparable also are the alternating hard and

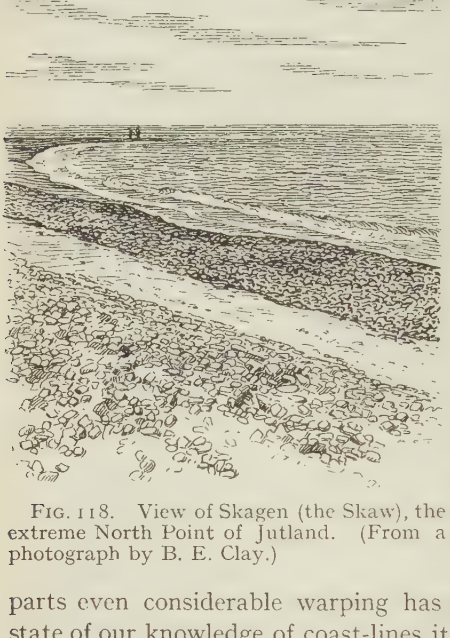


Fig. 118. View of Skagen (the Skaw), the extreme North Point of Jutland. (From a photograph by B. E. Clay.)

[1] In this case the rock is slaty throughout, but hard ribs of igneous rock strengthen the points at north and south.

[2] As in the case of the Great Australian Bight.

soft rocks which determine the embayments between Cumberland and Anglesey and between Start Point and Portland Bill.

*Spits of sand or shingle.* Having seen that the salient points of a bay consist of hard material, it seems odd that definite spits of land continue to exist when they are formed of soft material only. The best example is the Skaw (fig. 118) on the north coast

Fig. 119. View of the Chesil Beach from Portland.

of Jutland, but Spurn Point and Dungeness in our own islands present the same peculiarity. Standing at the root, so to speak, of the Skaw, looking out to sea, it seems incredible that its position should be marked far out by a continuous line of breakers, just as if it were a hard rocky ridge like Filey Brigg. One has to realize that, in such cases, one does not see the same material always, for new is being constantly added while the old is being removed. Thus here the conflicting currents of sandy-shored Skagerack and pebbly Kattegat collide with violence and have to drop their load, just as the current sweeping along the Chesil Beach piles up its pebbles against Portland (fig. 119).

All along our south coasts the work of the alongshore currents is most persistent, and is also helped by the fact that the heaviest waves are produced by gales from the south-west. Not only this,

but the flood-tide passes up the Channel from west to east. As a result of all these forces combined, and in spite of the attempt to stop it by means of breakwaters, a regular west to east movement of shingle continues. We may remember that when, as children, we frequented beaches, although we could step easily on to the top of a breakwater one side, it was a very high jump down the other.

This brings us naturally to the more widespread, although less easily observed, work of deposition done by the sea, namely, the formation of shoals and sandbanks. These frequently accumulate near the shore owing to differential movement of the water, chiefly in the form of alongshore currents. Along the coast of Europe from the Skaw to Calais, more or less all the way, sandbanks are forming parallel to the coast ; also, on the other side of the North Sea, they are found from Flamborough to the South Foreland. These, owing to their shifting nature, are very dangerous to navigation ; they all have to be charted, and many are marked by lightships, lighthouses, or buoys. Frequently they begin on the lee side of headlands, as has happened for instance on the east sides of Start Point and Portland Bill. The changing nature of these shoals sometimes cause the cross-channel steamers, plying between Dover and Calais,[1] to find difficulty in entering Calais harbour, owing to the shifting of the sand.

*Marine deposits.* Generally speaking, the material removed by waves and currents from the land becomes roughly sorted into sizes, the coarser fragments being dropped near the shores and becoming finer and finer further out. The finest is carried a very long way, and gives that somewhat turbid and usually greenish appearance to the sea that is characteristic of it, when viewed from the shore. Ultimately, however, all the solid material finds its way to the sea-floor, where it is spread out, so that any hollows there may be are gradually obliterated. This land-derived material never reaches the parts of the ocean most remote from land, but accumulating at various points according to its coarseness, forms very extensive deposits of definite and distinct

[1] See *Royal Commission on Coast Erosion*, vol. iii (Wyman & Sons, 1911).

characters, which are referred to in this work under 'Hydrosphere'.

Hardly distinguishable from these deposits, and yet of different origin, are those due to marine ice, which will be dealt with in another section.

*Geographical significance of outline.* The fact must here be emphasized that, although marine denudation affects the margins of the land only, yet in many cases these margins are, from the geographical standpoint, the most important part, in some inaccessible lands indeed the only important part. If we open our grandfather's atlas at Africa and compare his maps with our own, we see at once that man's conquest has always been from the coast inland; that, actually, the coast was thickly populated when the interior was still absolutely unknown, and one or two explorers penetrating it did so at the peril of their lives. The same state of things prevailed in Europe when rich trading-centres sprang up around the shores, while the impenetrable forests and swamps of the interior were frequented only by savage animals.

Even to-day the biggest cities of the world, or a very large proportion of them, are near the margins of the land, notably London, Hamburg, New York, and the Australian capitals. This being so, coastal waste is a matter of grave import wherever it goes on extensively. In our own islands it has been computed that a tract of land as large as the county of London has been swallowed up by the sea in the course of the last hundred years.

In 1911 the *Report of the Royal Commission on Coast Erosion* was published with a view to evolving means of checking the rate of destruction. The results of the Report are reassuring, for, although the loss is very great, yet it is more than compensated by the building-up processes carried on by rivers, combined with artificial means of reclamation.

# XXIV. Crust Movements

*Modelling not all due to surface agents.* Having dealt with the changes in the Earth's surface produced by external causes, which we have called the modelling agents, we must now describe those which are due to internal forces, but which come only to a limited extent within the sphere of geography. It has been already shown that changes of level on a large scale, but of a very gradual kind, are taking place in many parts of the Earth's surface, these being ascribed to the processes of contraction and consequent distortion known to occur in a cooling body. These changes, which appear so slight as hardly to concern the geographer, are yet of vast moment when we consider that the processes they indicate have continued throughout geological time.

*Warping.* Differential movement or warping is most easily noticeable near the coasts,[1] either because change of level is there more easily measured, or because in the case, for instance, of the Pacific, the movement is greater there than inland owing to the Earth's crust being in a state of tension. That certain parts of the Earth's crust are actually in a condition of special strain was emphasized by Professor Lapworth, whose theory of Earth movements on a grand scale drew attention to the fact that those lines of weakness or of maximum tension seem to coincide fairly closely with the regions of earthquakes and the volcanic belts.

*Earthquakes.* The immediate cause of an earthquake is difficult to explain in terms of geography, but it may be partly expressed as a sudden giving way of the rock some distance beneath the surface, owing to prolonged strain. Its physical results, as seen on the surface of the Earth, are to produce local

[1] Many cases are quoted, as for instance the existence of submerged forests. Professor Gregory describes a case on the Chilean coast where, in one place, the tops of trees are seen beneath the boat, and in another sea-shells are found at a height of 200 ft. Professor Gregory's friend likened these movements to 'a gigantic concertina played by the hand of Nature'.

differential movement, some portions of the rock being thrust upwards and some downwards, so that fissures are frequently formed. In an uninhabited region this is of no great moment; cracks may appear and may remain as gaping fissures, or become filled up with loose material. Unfortunately, however, the lines along which earthquakes occur happen, for various reasons, to pass through regions which attract a considerable population, and have hence proved disastrous to human occupation by promoting catastrophes of a very extensive kind. In centres of population, for instance, the very slightest earthquake shock causes windows to rattle, houses to shake, and people sometimes to be thrown down, but if the shocks are violent, houses sway and fall, fragments are shot up into the air, walls crack, and one part of a building may be piled on another. The terrible devastation wrought by the San Francisco and Messina earthquakes, and more recently that in China, horrified the world, and many equally striking examples are recorded in history.[1]

*Distribution of earthquakes* (fig. 120, *a*). The special lines of weakness referred to above as constituting earthquake-belts are:

1. The neighbourhood of the lines forming the world-ridges on the east and west sides of the Pacific Ocean.

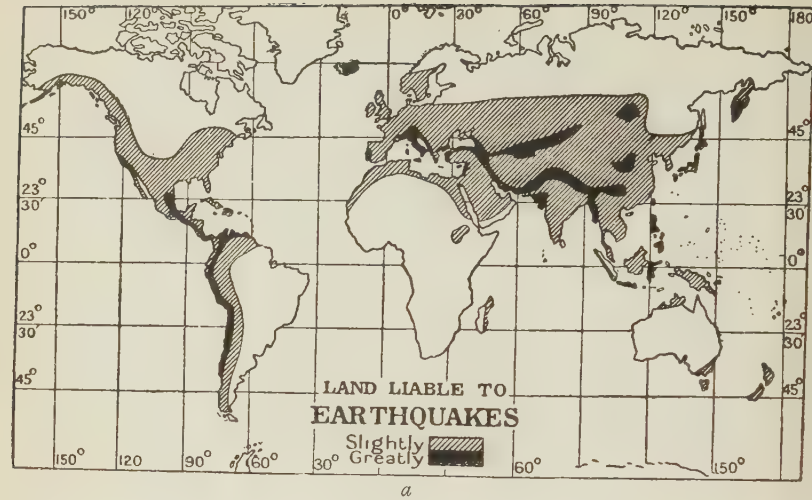
2. A zone extending east and west across the Old World, in the neighbourhood of the main lines of the Old-World Ridge. The most affected parts are the northern shores of the Mediterranean Sea and along a line extending from that region eastward as shown on the map.

Each of these lines is roughly a great circle on the Earth's surface, their angle of intersection being between 65° and 70°.

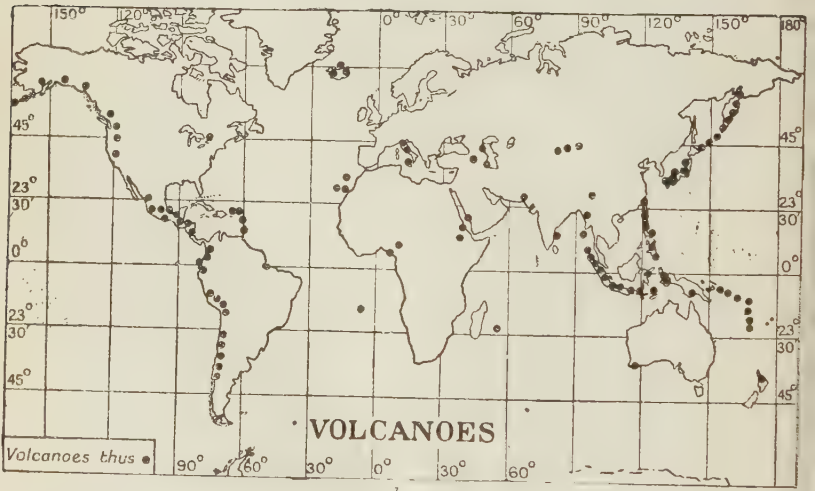
It has been calculated that 95 per cent. of the recorded continental earthquakes have happened along these lines.

The dangers of earthquakes are greatly increased by the fact that they occur near the sea, for the level of the sea and land relatively to each other is altered by them. A sudden movement of the sea-floor, in the neighbourhood, is often followed by a depression and huge destructive waves sweep over part of the land.

[1] The use of ferro-concrete in building will probably have a marked effect in reducing the results of earthquake action.




*a*




*b*

FIG. 120. (*a*) Distribution of Earthquakes ; (*b*) Distribution of Volcanoes.

In Lisbon, which is built partly along the shores of the River Tagus and partly also on a succession of terraces above it, the whole lower part of the town was overwhelmed by an immense wave, which rushed up the estuary.

Submarine earthquakes, sometimes designated as seaquakes, are movements taking place beneath the sea, but unless they arise in connexion with the land, their results are only seen in the form of great waves, called tidal waves, which are occasionally met with, two or three together, in the open ocean.

As geographical factors in altering the distribution of population, earthquakes are almost negligible, for the sea-margins of continents being most attractive to population, the dangers inherent in these regions are either disregarded or special methods of house construction are adopted with a view to minimizing danger. In Japan, where as many as eleven earthquake shocks have been known to occur before breakfast, the houses are more or less earthquake proof, but even so the strain of uncertainty sometimes becomes too much for Europeans, the Japanese temperament seeming in this respect to be more phlegmatic.[1]

*Volcanic action.* Vulcanicity is of far more geographical importance than seismic force, and although, being more easily traced, it appears more widespread, it really occurs along the same general lines.

Volcanic action is the evolution of force within the Earth, which causes material from the interior to be extruded on the surface, either violently through a vertical funnel called a vent, or gradually through a vertical fissure that may be of very great horizontal extent. The actual cause of a volcanic eruption is not clear. Frequently it is accompanied by earthquake shocks, and hence may be partly attributable to the same cause, namely, increase or decrease of tension in certain weak portions of the Earth's crust. It has been believed that steam plays a part in the outburst, the source of the steam being water, which has filtered in through cracks, and has been derived possibly from the sea. Lately, however, investigators have had reason to doubt

[1] For a good account of earthquakes and for photographs of their effects see Hobbs, *Earth Features and their Meaning*.

that steam is always present, but even without it expansion due to chemical changes might account for disturbance. There is some uncertainty as to whether the Earth's interior, even if generally solid throughout, may not in those parts be of the nature of a honeycomb filled, as it were, with lava as honey, or whether the melting of the rock takes place as part of the eruption.

In geography, however, the important part of volcanic action is not cause but effect, and the effects are twofold according as the eruption is a tranquil one or otherwise. The most important results of eruptions, geographically speaking, are those of which we know least, they being due, as we believe, to fissure eruptions.

*Fissure eruptions.* Fissure eruptions are usually ascribed to the tranquil welling out of lava from an extensive fissure. By this process huge areas have been overspread with a layer of volcanic material, and thus the whole nature of the surface has been changed. The most striking cases of this are seen in :

1. The Dekkan of India ;
2. The Snake River region of the western United States.

In both of these regions, lava covers a surface of 20,000 square miles, forming a deposit from one to two or even three miles thick. Other extensive plateau formations of lava are seen also in Iceland and in the western islands of Scotland, the last of which form part of a once much greater lava-sheet reaching across to the north of Ireland.

These lava formations are extremely important geographically, because the soil derived from the lava still retains large quantities of soluble salts, highly valuable for the well-being of plants. Therefore a lava surface of this kind, if sufficiently well watered and in a good climate, is extraordinarily fertile, as in the Dekkan, where a teeming population makes a living by agriculture. Exactly how these massive eruptions occurred we do not know ; it seems almost as if they may have belonged to an earlier period of volcanic activity. The fissure eruptions of Iceland have taken place in historic times, and seem comparable, but the only quite recent manifestation of the kind is that which occurred at Tarawera, in the

North Island of New Zealand, in 1886, and wrought considerable havoc on the surface, destroying the famous pink and white terraces.

*Tranquil volcanic eruptions.* The eruptions in the Hawaiian Islands are of a tranquil type, but they are probably due to true volcanoes, as some slight accumulation of material takes place around certain centres (fig. 71, *c*). The passivity of these and the extreme gentleness of their slope, owing to the liquidity of the lava, makes them form a kind of link between fissure eruptions, which seem to eject lava only, and the better-known type of volcanic action which usually results in the formation of a cone.

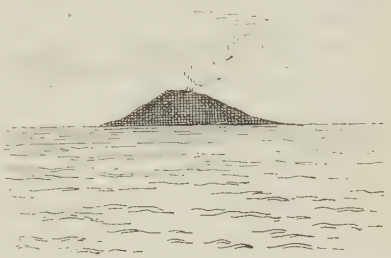


Fig. 121. Stromboli in eruption, showing outburst through a vertical fissure. (From a photograph by Will R. Rose, Chester.)

*Explosive volcanic eruptions.* Volcanic eruptions of the more ordinary type, i. e. those which emanate from volcanic cones, are of more picturesque appeal than fissure eruptions, but are important only as endangering life in their immediate vicinity. This type of outburst takes place through a vertical funnel or vent, often by the reopening of a former vent more or less central in the mountain; less often by the formation of a new vent or of sporadic cones anywhere about its surface. Of the former case Vesuvius is a type, and of the latter Etna. The vent being more or less vertical, the material ejected tends to pile itself up round it, thus forming a mountain. This was well seen in the case of Monte Nuovo near Naples (fig. 71, *a*), which built itself up in a single night, and in the huge spine of Mont Pelée (fig. 71, *b*), which towered upwards only to be destroyed almost as soon as built. Sometimes, however, an eruption has the opposite effect and a violent explosion removes material, as in the case of the Krakatoa eruption (1889), where two-thirds of the island disappeared.

*Material ejected from a volcano.* The material ejected is either: (*a*) *gaseous*, as was the case in Martinique, where poisonous gases,

partly incandescent, either suffocated or burnt the unfortunate inhabitants of St. Pierre, and only a few were saved from the ships, by throwing themselves into the sea ;

(*b*) *solid*, when it is classified according to size into dust, ashes, scoriae, lapilli, or bombs ;

(*c*) *liquid*, either as lava, which subsequently hardens into solid rock, or as fine mud, formed of the dust mixed with water, as happens when there is heavy rain.

The solid fragmental material, roughly sorted according to its weight, tends to pile itself up around the central orifice, so that if by any chance the structure of the mountain is laid bare alternating layers of finer and coarser particles are disclosed, each arranged around the opening at the angle of rest of loose material. It is interesting to record that the poet Goethe seems to have been first to claim this structure for a volcano, in opposition to the view propounded by the geologist Werner, and generally held at that time. Werner's theory was that a volcano was like a blister, the surface of which is domed by the pressure of liquid from beneath, the liquid in this case being lava.

If the fragmental material is very fine indeed, it may be shot up into the air to a great height and then descends over the whole surface for miles round. This is why so much volcanic matter is found on the ocean-floor, as there, in the great depths, it hardly becomes mingled with other matter. In the Martinique disaster the fine dust, consisting of minute glassy fragments, clouded the air and finally formed layers several inches deep even on islands long distances away, such as Dominica and Barbados. A rider in Dominica found his eyebrows, eyelashes, &c., completely clogged with the dust, so that he was quite unrecognizable. In the Krakatoa eruption the dust was shot up into the air above the immediate layer of changing winds, and the higher currents of the atmosphere carried it several times round the Earth. Occasionally the effects of the lava-flow from a volcano may be of far-reaching importance, as for instance when it crosses a river valley. Then the river is ponded back and acres of fertile land are swallowed up by the waters of a lake. Usually, however, the effects of this type of volcanic activity

are of strictly local significance, the only misfortune being that volcanic soil is so extraordinarily fertile. Because of this, vast numbers of people, careless of the danger involved, often settle in the immediate vicinity of a volcano, even, as was the case with Vesuvius, cultivating the interior of the crater itself.

Although volcanoes as such are of comparatively slight importance to geographers, yet they have always commanded considerable attention in the pages of geography books, chiefly because of their almost dramatic interest. For this reason certain points in connexion with them must be cited.

*Forms of volcanoes.* In the first place, the form is characteristic, and gives rise to a well-marked and unmistakable feature (fig. 121). A typical volcano, for instance, is conical, and its sides have the angle of rest for loose material, easily recognized by those who are familiar with coal-tips, &c. The cone may be perfect or nearly so; more often it is broadly truncated at the top, owing to an explosion having removed it at some time, as is seen in Fuji-yama, or it is breached at the side like Vesuvius. Moreover, as in that mountain and in Auvergne, the truncation may be asymmetrical; also smaller cones may be built up in the truncated area, which is called the crater, or anywhere on the surface of the mountain.

Further variations of form arise, owing to whether the material is:

(i) Composed entirely of fragmental solid material (fig. 71, *a*);

(ii) Composed partly of this and partly of solidified lava;

(iii) Composed entirely of solidified lava (fig. 71, *b*).

The first is a cinder cone; the second a composite cone; the third a lava cone.[2]

If the material formed as in (iii) is extremely fluid, we get an exceedingly gentle outline, as in the Hawaiian volcanoes (fig. 71, *c*).

*Irregular forms of volcanic and of more deep-seated origin.* Irregular forms of volcanic origin are lava-streams from which the surrounding softer rock has weathered away. Goat Fell, Arran, and the Giant's Causeway are examples; or if the rock has solidified beneath the Earth's surface and the cover has been

afterwards partially or wholly removed by denudation, we find bosses, sills, and dykes as a result. These rocks are not called volcanic, as they never flowed out on the surface, but their origin is exactly similar, only more deep-seated, so they are called intrusive. Such are Dartmoor, the Cairn Gorm group

Fig. 122. Drawings of the Whin Sill to show the prominent feature resulting from the intrusion.

and many others in the Scottish Highlands, Criffel, a marked feature in the southern uplands of Scotland, the Whin Sill (fig. 122), and countless others, all of which betray their origin to the geologist. They must be recognized and taken into account by the geographer also, in appraising the features of a district.

In the second place, the distribution of volcanoes seems to follow certain definite laws, and may become increasingly important as we learn more about the forces that direct the changes in the Earth's crust and interior.

*Distribution of volcanoes.* Referring to the map (fig. 120, *b*) which

shows the distribution of earthquakes we find that the belts of special volcanic activity are, in the main, identical with those where earthquakes occur. Volcanic eruptions indeed are sometimes accompanied by earthquake shocks, but this is not invariably the case, and sometimes the two phenomena appear to be wholly unconnected. Earthquakes may occur in consequence of any purely local strain in the Earth's crust, but volcanoes are limited to certain well-defined areas. It is, however, clear that the main belts of volcanic activity correspond with those where earthquakes are most frequent. It may be possible some day to account more easily for the distribution of volcanic activity, supposing we can discover a definite connexion between it and the position of the 'world-ridges' described above. If Professor Lapworth's theory holds true, certain major folds have affected the Earth's crust on a grand scale, forming an arch of continents opposed to a trough of oceans, and at the junction of arch and trough, where strain would be greatest, these ridges and also the belts of volcanic activity occur.

Thus, one volcanic belt marks the line of the great western world-ridge, which forms the east side of the Pacific Ocean; a second ranges itself all along the eastern limb of the great eastern world-ridge, and with the first makes up the 'ring of fire' encircling the Pacific Ocean; a third coincides, more or less, with the western limb of the Old-World Ridge, and extends in a curving line from Iceland through the Mediterranean trough and along the north and south rift of East Africa. There are also certain lines of volcanic activity within the ocean basins, especially in the centre of the Pacific Ocean and down the middle of the Atlantic. All the oceanic islands which are not coral are of volcanic origin, and perhaps parts of some of the coral ones as well. The belief that some connexion between the world-ridges and volcanic and seismic activity really exists is strengthened by the fact, pointed out by Professor Milne, that most earthquake shocks occur along the lower part of the steep slopes of these ridges.

# XXV. Land Forms in Regions other than Temperate

*Land forms in desiccated areas.* The fact that the distribution of man on the Earth coincides so nearly with that of vegetation tends to render the land forms of those regions so familiar, that it is difficult for us to realize that they are not of universal occurrence on the Earth's surface, and that beyond our ordinary ken there are vast regions subject to quite different conditions and, consequently, presenting an entirely different aspect. Hitherto we have been describing the features characteristic of regions where the rainfall is sufficient and where the curve of erosion forms the dominant outline; we now find there are two other strongly contrasted types of scenery, resembling one another, however, in one particular, namely, that the outlines are not obscured by vegetation, and that most often the attack of the modelling agents is on the bare face of the rock itself. In these two cases alike, the topographic forms are due rather to the structure of the rock, than to shapes assumed by the accumulation of disintegrated material, although such accumulations do occur. It must not be assumed that, in any region, the same conditions have always prevailed, and this tends to complicate the character of the scenery, as certain features may have originated prior to the setting in of any particular set of conditions.

The two types of climate which give rise to these somewhat specialized and unfamiliar forms are:

1. The hot dry climate, found more particularly along the tropical belts of high atmospheric pressure;

2. The cold dry climate, the dryness of which is due, not to the absence of atmospheric moisture, but to the temperature being too low for rain to form.

*Land forms of hot dry regions.* Considering first the effects produced where the temperature is high and precipitation extremely rare, we find that the modelling agents are mainly (1) extremes of temperature, and (2) wind. In some deserts

these seem to have been assisted by the action of occasional but violent rain-storms, which have been known to produce a marked feature in an astonishingly short time. The dry valleys which characterize a desert landscape may not all have been formed in this way, as some may have existed before desert conditions set in, or even wind may produce a very good imitation of a valley.

The old idea of the desert, and still the first one in the mind of a child, is that it consists of great level stretches of sand, something like an exaggerated sea-beach. This is, in part, true of some deserts, but it is necessary to distinguish two main types, the sandy and the rocky desert. Above one-third of the Sahara desert is sandy, but the rest is rocky and is traversed by chains of mountains, averaging about 2,000 ft. in height.

*Forms seen in sandy deserts.* Sandy deserts occur chiefly in depressions, part of the Sahara being below sea-level. Even here the aspect, though vastly monotonous, is diversified by sand dunes, which cover a great part of the surface and vary in height from monticules to almost mountains. The sand dunes of the desert are similar in shape and structure to those which characterize sandy shores, being also of aeolian origin, but they do not maintain a steady forward march as do those of the sea-shores, many being stationary and in part due to the presence of an obstacle, though this may be merely the sand itself. In the desert of Sinai, numbers of little hillocks are formed, each round a mat of coarse vegetation ; these are not ordinary dunes and are called ' Neulinge '. Wind, blowing across these sandy wastes, frequently produces on the surface a structure exactly similar to ripple-markings, each ' ripple ' being really a dune in miniature. The work of the wind is both constructive and destructive ; it produces the dunes and has also, in the course of ages, removed much sand from some parts and piled it up in others. The ancient cities of Babylon and Nineveh are buried deep below the present surface-level, and in excavating for the Suez Canal remnants of ancient cuttings of a similar kind were unearthed, showing that the nineteenth century had not originated the idea of a canal. The wind's destructive work is greatly assisted

by the sand which it carries ; this is not raised much above the floor and so anything lying on the floor is undercut. The polishing effect of the sand was strongly marked on the surface of Cleopatra's Needle, which had lain half-buried in it for centuries. Where sand-covered, the obelisk retained its inscriptions, but these had been polished away on the exposed surfaces. Sandy deserts are more favourable for travellers than stony ones, as water occurs in the neighbourhood of dunes, either at the surface or not far below.[1]

*Forms special to stony deserts.* The stony desert is usually a plateau or a series of plateaux, more or less divided up by winding watercourses, now dry. These have probably been produced at some period by the terrific cloud-bursts which characterize these regions. The sides of these dry valleys are abrupt and bare and their form is step-like, the angle of each step being filled in by a pile of steeply sloping talus. Exposed as they are to the action of the wind, the valley-walls become fretted and honeycombed upon the surface and are frequently undermined by the force of wind, assisted by sand blown along the desert-floor. Their decay is rapid, for the differences between day and night temperature may amount to 70° F. and the stresses thus produced suffice to shatter the rock, thus rendering its equilibrium unstable. In the hot day-time, explosions like pistol-shots accompany the separation of rock fragments, and a train of camels winding along one of the deserted waterways may appear to be saluted by a round of musketry, fragments being so lightly poised that the slightest vibration suffices to dislodge them. In a much-dissected desert plateau, if the rocks are level and of different hardness, we get the characteristic outlines so often described in the Colorado region. The hard rock, which has already been dissected into blocks, preserves the softer layers immediately beneath the block. Thus tabular eminences are formed, the sides of which are modelled by the action of the wind. These characteristic table-topped elevations were described by Walther as 'Zeugen' and correspond to the 'mesas' of the

[1] For photographs of the sandy desert see E. de Martonne, *Géographie physique*, p. 652.

Colorado. If the hard layer is absent, the shape becomes irregular and needlelike, rather resembling the Eastern Dolomites in form. In the Colorado region these are called ' buttes ', a name first given to accidentally similar structures in France, e. g. the ' Buttes Chaumont ' near Paris. Other shapes partly due to undercutting are the curious mushroom-like forms ; structures rather like these are known even in temperate countries where

FIG. 123. Desert features, Reg Desert, Sinai. The highlands form a sharp angle with the flat floor, and their outline shows the abrupt straight-lined features of house-roof structure.

wind action gets the upper hand, for example the Brimham Rocks near Harrogate. The prolonged work of sand-laden wind upon rock of varying composition may produce a weird effect of arched galleries and other fantastic forms.

*Desert configuration generally.* The configuration in deserts of the hot type is distinguished then, as stated above, by a complete absence of the curve of water erosion. This curve, which produces the softly flowing outlines of temperate lands and which corresponds actually with Hogarth's ' line of beauty ', is replaced by the peculiar and jagged ' house-roof ' structure characteristically developed in the Sinai Peninsula (fig. 123), combined with an angle of junction between hill or mountain and flat floor. Thus, for the

most part, desert forms are bounded by straight lines, as seen also in the steep-sided, often step-like valleys, the flat-topped mesas, and the pointed pyramidal buttes. The ruggedness is not softened by atmospheric effect, which often adds subtlety even to the bold contours of ice-formed peaks, for the dry clearness of the air tends to harden outlines and brings into prominence the features of sunny and shady side alike. Curves are present, indeed, namely the convex curve of the sand dune and the concave one on the sides of mesas. The first of these, however, is monotonous and unvarying, being produced by the slipping of fine particles over one another until they become piled up at the somewhat steep angle of rest. The latter are also regular and are ascribed to wind, with chemical action just below the cap where a little moisture may be retained. Geikie describes the 'bad-lands' as tracts of irreclaimable barrenness, blasted and left for ever lifeless and hideous; and the same description might almost be applied to the hot deserts generally were it not for the contrasts offered by the oases, which gleam like jewels in a dull-gold setting, and the matchless wonder of the sunset skies. The distribution of hot dry deserts follows certain laws which are explained in the section devoted to 'the Atmosphere'.

The cold dry[1] desert is a waterless[1] area, remote from the sea, in regions where the temperature of the air is below the freezing-point of water. Deserts of this kind are found within the Arctic and Antarctic circles and are even more destitute of life than the hot dry desert, unicellular algae being almost the only living forms that can survive these conditions. Photographs and sketches taken by explorers have to some extent familiarized us with the special features of this kind of desert, which can be studied also on a small scale, but less typically, above the snow-line in all parts of the world. The character peculiar to the cold dry desert is that the Earth's surface is here obscured by a mantle of snow and ice, and the features which appear, therefore, are those assumed by water in the solid state. The snow, which here takes the place of rain, remains, except for evaporation, where it

[1] The words 'dry' and 'waterless' are here used in the sense of 'devoid of water in the liquid state'.

falls. Fresh snow, falling on this, causes it to consolidate into ice; thus a sheet of ice, sometimes powdered with snow, covers the ground. In the centre of Greenland the 'inland ice', as it has been called, is in the form of a very slight dome, but to the eye appears of almost uniform level, as Nansen's sketches show (fig. 124). Resting on an elevated plateau, it stretches away as far as the eye can see, producing an appearance of unvarying and arid monotony, which is, however, wondrously relieved by the changing aspect of the heavens. Towards the margins of the ice-sheet, the nunatakker,[1] or projecting mountain peaks, become more frequent as the ice-dome slopes seawards. In Greenland a rampart of mountains holds up the ice-sheet, and it ends some distance from the coast, discharging its ice by means

FIG. 124. Drawing to show the inland ice in Greenland. (After Nansen.)

of glaciers. A strip of land, which is quite fertile in summer and crowded with life, forms the coastal margin. In Antarctica the part which has been explored has no fertile strip, but a wide mountain belt extends to the coast and is traversed by the great outlet-glaciers. The ice is not stationary,[2] but moves towards a lower level. If the surface is nearly flat it sends out great lobes; if not, it cuts out couloirs and cwms, the latter encroaching on one another to form finger-valleys. The glaciers given off from its margins flow downwards towards the sea, where large blocks of ice, becoming detached from them, float away as icebergs. The slope of the land and its irregularities often cause the ice of the glaciers to be much strained; it is

[1] A 'nunatak' is 'a solitary peak'. When the heat radiated from the rock dissolves the snow the projection, which may resemble a ruined castle, is surrounded by a 'moat'.

[2] The ice appears to be almost stationary inland, but its glacier outlets may cover from 50 to 100 ft. a year.

then traversed by crevasses, so that one of the greatest difficulties that Nansen encountered was getting on and off the inland ice.

The interior of Antarctica is the greatest extent of cold dry desert known. Here the land itself, as far as it has been explored, consists of a lofty plateau, 8,000 to 10,000 ft. high, bordered in some parts by high mountains, extending for miles along the coast, or it ends abruptly in cliffs of considerable height. The surface of the plateau is covered by a great sheet of ice, which was found by Scott to be of almost uniform level. This 'inland ice' does not, as a rule, quite reach the sea, but glaciers emerging from it travel in that direction and sometimes extend thither. In one part of South Victoria Land, however, the inland ice itself acts as feeder to an ice-sheet, which overspreads the coastal plain and is continued some distance over the sea's surface, terminating in a long cliff-like wall of ice, which is called the Ross Barrier. This is 400 miles wide and moves at the rate of 500 yards a year; from it icebergs, often of some miles extent, with characteristic flat tops, become detached.

The margins of the continents in these glaciated areas do not form part of the true desert region as conditions there, especially in Greenland during certain seasons of the year, are favourable for life, and both plant and animal forms flourish in great abundance, although the species are restricted. The proximity of desert and fertile conditions is often quite startling; Peary one day descended from the inland ice into a quiet valley, filled with flowers and the hum of bees, where musk-oxen were idly grazing.

In the process of denudation of the cold dry desert, wind, as in the contrasted hot type, plays a dominant part, affecting the whole surface, whether snow-covered, or bare of snow and ice. The powdery surface-snow is removed in masses by the wind, so much so that the footprints and sledge-tracks of a previous year's journey in Antarctica were subsequently found, standing up in relief, an inch above the general level of the surface. The snow thus removed is piled up in sheltered places and forms dunes, similar to sand dunes. The ice-sheet itself is often bare of snow and is covered with a shiny crust, traversed by cracks, like the muddy bottom of a pond. This seems to point to the fact that

evaporation equals or exceeds deposition. Where the bare rock is exposed, its surface is often polished and pitted by wind, as in the hot desert, the wind in this case being laden with dust particles detached by frost. During the short summer, water plays no important part. It helps, however, to produce the stratified effect of the ice, seen in the glaciers, by washing rock-dust and fragments over the surface. In Greenland, where water in summer is more abundant, it can often be heard, if not seen, as it works its way down between the ice and rock. Also, as snow melts, the water so formed percolates into cracks in the rocks, thus making possible the subsequent work of frost. The work of water in its frozen state throughout this desert region is both protective and destructive. As snow, its function is mainly protective, but, as mentioned above, it supplies the tool which does the destructive work of frost. Frost action is not so conspicuous as would have been expected, as so much of the loose snow is blown away by the wind. The leeward sides of projecting rock-faces are, however, attacked and bold outlines are thus produced. The usual results of ice action can be recognized everywhere at the margins of the ice-sheet, especially where the ice is receding, which seems to be almost universally the case. The prevalence of these forms attends the dying out of glaciation, so they are best studied in regions where the glaciated floor is being, or has been, bared. They are described above under ' The Work of Ice '. In this connexion it is noteworthy that the ' cwm ' or ' cirque ' formations, exposed on the slopes of the Royal Society range in Antarctica, furnish the most extensive example of that kind of action, known anywhere in the world.

# SECTION VI. THE BIOSPHERE

## XXVI. General Conditions of Life

*Conditions necessary to life.* Wherever the atmosphere, hydrosphere and lithosphere are in contact and intermingle in such a way as to make life possible, a mantle of living matter clothes the Earth. This is often, and perhaps rather fancifully, called the biosphere, the term being convenient as expressing in one word the whole of the various forms of life. The special conditions upon which life depends are light, warmth, moisture and air for respiration; these, moreover, greatly modify the amount and extent of its distribution, so that the living matter does not cover the whole surface of the globe and is not continuous.

At the same time, there are exceptional forms, both in the plant and animal worlds, which can dispense, more or less completely, with one or other of these conditions. Thus, some plants, like the common mould, need no light; deep-sea animals also have no light from the Sun, only that proceeding from the phosphorescent organs which many possess. Sustained warmth is absent in the case of snow algae, and animals such as penguins, polar bears, and others can almost dispense with external warmth. Even moisture, so essential to life, is absent for a great part of the life of geophilous plants, which have the power of remaining quiescent during drought. These same plants and hibernating animals can survive long periods without food, yet, generally speaking, normal plant and animal life depends so entirely on these conditions that where one or more is wanting, life becomes sparse and difficult.

Throughout the period of its existence on earth, life has remained similar in kind, as we know by the geological record, which forms a fairly continuous chain. The more we discover about the past, so much the more do the chief gaps tend to become bridged over, so that, no matter how different forms may appear, they seem to belong to the same general types. The life of the

Earth is self-contained, having apparently been always limited to itself; it has received no reinforcements from outside and contributed none. The nearest planet, Mars, if it supports life, must have an entirely different kind, owing to the immense difference in the density of the air surrounding that planet.

*Land life compared with ocean life.* Comparing the forms of life on land with those of the ocean, we find that, on land, the dominant need of living forms is moisture, whereas in the ocean the chief struggle is to obtain a sufficiency of light. On land the range of life is limited both vertically and horizontally, the division of the land into continents and islands tending to form boundaries and to help differentiation. In the ocean, on the other hand, there seem to be no definitely sterile areas and life is far more abundant than on land, moreover the whole region is continuous and no hard and fast boundaries exist. We observe, therefore, that marine life is, on the whole, less varied and less differentiated than terrestrial, while lower forms are present in greater numbers and the highest forms of life do not occur. On land the highest forms of life flourish and abound, side by side with the lowest; there is greater differentiation and far more rapid development.

*Extent of life-zone on land.* Considering first the extent of the life-zone on land, we find it must have fluctuated greatly in a horizontal direction. In former geological periods, living forms of almost tropical type flourished in regions of now arctic cold, as for instance the luxuriant fern and cycad growth found embedded in rocks of East Greenland. On the other hand, evidences of the existence of an arctic flora in past times in India are incontrovertible. This is doubtless owing to climatic change, which is of the first importance in regulating life-distribution on land.

At the present day, the life-zone on land may be said to extend wherever the temperature is not permanently below freezing-point, provided there is a sufficiency of moisture. This limits it roughly to the tropical and temperate zones. Beyond the North and South Temperate zones, life becomes precarious and special adaptations are necessary for it to be preserved. The

living mantle, therefore, thins out gradually towards the poles, dying away altogether in polar regions. The main cause of this dying out is drought, as though water is present in these latitudes, it no longer exists in liquid form. Similarly, life dies out in regions of hot drought, notably in the deserts of the trade-wind belts. So long as moisture is present, plants of some kind seem able to exist in spite of heat; certain algae, for instance, in New Zealand are found in water that is nearly boiling.

Thus, on land, the life-zone is limited to those parts of the Earth's surface where sufficient moisture for plant life is available; hence it practically varies directly with the rainfall, so that a map of the rainfall represents roughly the extent and density of the biosphere on the land-areas of the globe. Animal life is so bound up with plant life that its range is almost identical, although different laws govern its variations. The rainfall map (fig. 22) can be roughly transformed into a map of the biosphere (fig. 125) by using the scale thus:

Over 80 inches: tropical forest;
40 to 80 inches: tropical forest merging into savanna within the tropics;
belt of evergreen trees outside the tropics;
20 to 40 inches: savanna within the tropics;
belt of deciduous trees outside the tropics;
10 to 20 inches: savanna within the tropics;
steppes outside the tropics, merging into coniferous forest;
under 10 inches: desert.

The first four of these vegetation areas designate the boundaries of the biosphere, properly so called; but some forms of life, mainly animal, extend to a limited degree beyond them.

*Distribution of life in the ocean.* Considering first the distribution of ocean life a little more in detail, we find it is regulated by the amount of light-penetration. Plant life, for instance, is limited to the photic zone, i.e. to that part which is penetrated by light-rays proceeding from the Sun. This zone, which extends downwards to a depth of from about 600 feet near the continents, to somewhat

FIG. 125. The Rainfall Map as Map of the Biosphere.

less than 5,000 feet [1] in the open ocean, comprises all the shallow and superficial parts of the ocean, and in it plant life is found at every depth, either fixed upon the sea-floor or floating at or near the surface. Here flourish various kinds of algae, which form vast floating meadows, upon which the countless creatures of the sea graze their fill and, in their turn, fall a prey to the greedy flesh-feeders. The limit of the photic zone, which is also the limit of living plants, is, near the continents, almost coincident with

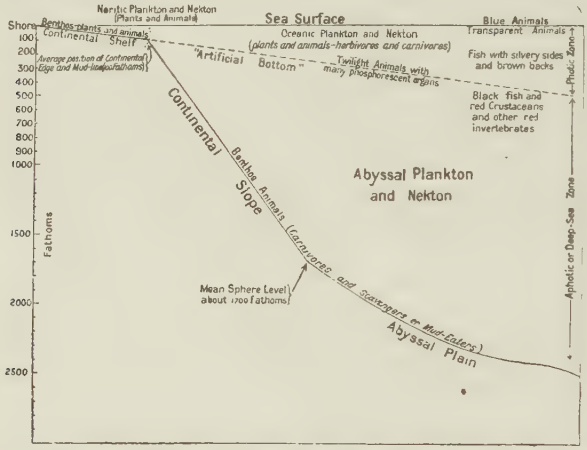



FIG. 126. Diagram showing the photic and aphotic zones separated by the mud-line and the artificial bottom, also the oceanic faunal and floral areas. (From *The Ocean*, by Sir John Murray.)

the position of the mud-line, the level at which fine mud begins to form on the ocean-floor (fig. 126). The mud is formed partly of fragments of organisms, in contrast with the sand which is produced by the breaking up of land-derived material. At the level of the mud-line, sloping downwards from it to the depth where the photic zone ends, is the so-called 'artificial bottom', which is formed by the arrest there of material sinking from above, owing to the increased density and viscosity of the water. Both this and the mud-line constitute important feeding-grounds. Below this level no living plants are found, but their dead remains

[1] The rays are differentiated at increasing depths; very few red rays penetrate as far as 1,500 ft.

and those of surface-living animals form part of the food of the denizens of the deeper sea. Of the deep-sea animals, it is not at present clear what proportion dwells in the intermediate depths and which are bottom-living, but certainly bottom-living forms abound in coastal waters and decrease greatly in numbers as deeper water is approached. Perhaps those which live in the greatest depths have only migrated thither owing to the struggle for existence being less severe there than elsewhere.

Broadly speaking, ocean life seems to be most prolific as regards number of *individuals* in the colder waters,[1] but the number of *distinct species* is far greater in the tropical seas. A high temperature is favourable to the life-processes, so that metabolism probably goes on far more rapidly in the latter; it has, indeed, been estimated that, in the colder seas, increase of individuals goes on at only one-third the rate. As, however, the same calculations tended to show that the life of the individual in the colder seas is prolonged something like a thousand times, it is clear that each one must be far more prolific. This fact may account for a greater abundance of food-supply in the colder seas, whereas the presence of denitrifying bacteria in the warmer tends to produce a scarcity of food-material, the nitrogenous salts being gradually reduced to nitrogen, which would pass into the atmosphere.

To summarize: the sea, as a whole, is believed to contain a considerably larger number of species than the land, for, of plants and animals together, there are probably at least 500,000. The species are, however, less highly organized for the most part, and, in tropical waters especially, a very large proportion of the lower forms of life prevails. Although the whole area is continuous, definite temperature provinces can be made out in the case of shallow-water animals,[2] but the chief determining factor in the general distribution of organisms is depth. Plants in

[1] A sample of water, taken at 7 fathoms near Kiel, contained fifty times as many microscopic organisms as one from tropical seas. The tropical 'desert' zone, between 30° north of the equator and 20° south, is five times less populous than the temperate zones.

[2] See Fischer, Paul, *Manuel de Conchyliologie* (Paris, 1887), map facing p. 126.

a living state are limited to the shallow and superficial layers, but animal life extends throughout, being most abundant in the shallower parts of the seas and least abundant in the deepest parts of the ocean.

It is important to note that the distribution of marine animals, especially fish, is in very close relation with the well-being of man. This point was clearly shown in 1915–1917, when, owing to the presence of mines, fishing was greatly restricted. Relatively few fish were marketed from the North Sea, and this resulted in an increase of the stock, especially of flat fishes.

*Distribution of life on land.* With regard to life on land, it has already been mentioned that rainfall is the dominating factor in determining its amount and extent; the whole scheme is, in fact, regulated by the availability of nourishment.

Plants typically depend on being able to extract food-material from the atmosphere and from the soil; for the former process they must have sunlight, and for the latter moisture. Some animals derive their nourishment from plants and others by devouring each other; obviously, then, there are far more plants than plant-feeders and more plant-feeders than flesh-feeders.

The discontinuous nature of the land has led to the establishment of well-defined provinces of animal life; it is not, however, necessary in a work of this kind to give details of the zoological provinces, for these, though significant biologically, have little to do with the life of man, which is the main subject of geography.

Plants, however, being more mobile than animals, are less subject to limitations; moreover, the kind and extent of the vegetation in any part of the world have had a profound influence on the life and occupations of the human race and have thus materially guided its distribution.

Hence it is important to note here that plants, being affected primarily by the amount of moisture and heat obtainable, have their lives determined mainly by latitude and altitude. The diagram (fig. 127) illustrates the interrelation of these two factors, but there is also a gradual diminution in luxuriance and variety of vegetation from the equator to the poles and from sea-level to mountain-top.

By referring to the description of the biosphere as applied to the rainfall map given above, it will be seen that the horizontal extent of the various vegetation areas is more or less zonal in arrangement.

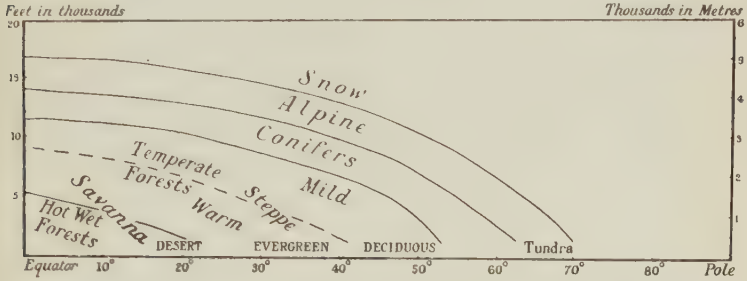



FIG. 127. Zones or Girdles of Vegetation, both vertical and horizontal.

Thus there is :

(*a*) An equatorial belt of tropical forest (over 80 in.), graduating northward through

(*b*) Savannas or grass-land with mixed woods (40–10 in.) to

(*c*) Hot dry deserts (under 10 in.).

These graduate again through :

(*d*) More grass-land (steppes) (10–20 in.) and more mixed woods (20–40 in.) and

(*e*) A belt of coniferous forest (10–20 in.) to

(*f*) Cold dry deserts or tundras (under 10 in.).

These belts are repeated southward only as far as (*d*) owing to the broken-up extent of land.

It will be necessary, in dealing with human life, to refer to these zones again and again, for their varied character has a profound influence on the occupations of the human race and hence materially affects its distribution.

Although these belts keep always in the same position relatively to one another, it is important for us to realize that they are not fixed in situation and extent, but depend entirely on climate, which in course of ages varies very considerably. Even within a lifetime we are able to observe that oscillations of climate on a small scale have taken place, these being generally ascribed

to the periodicity of sun-spots. When sun-spots are numerous, as is the case every eleven years, storms diminish along a certain belt but increase both north and south of it. Evidence is gradually accumulating to show that these eleven-year periods form part of much longer and more extreme oscillations, sufficient to cause some slight general shifting of the climatic zones and hence of the vegetation zones also. Thus we may suppose that the increased precipitation, which produced extended glaciation in the north, synchronized with wide deposits of wind-produced loess further south, in a region then becoming desiccated. Only by the shifting of these zones since the Human Period can we account for such anomalies as the remains of cities and walled-in fields in desert areas and, on the other hand, of irrigation works in damp ones. Even now the desert region is expanding on the north, where the sand dunes are all on the move and the shrinking lakes are producing concentric strands, while on the equatorial side of the desert-belt the dunes are fixed and the lake-basins show no signs of evaporation.

It is quite possible, as will be referred to again below, that some of the restlessness of peoples during the world's history may be ascribed to this cause, as a gradual desiccation of regions once favourable to life seems to have taken place over large areas in Central Asia and would offer a material incentive to migration.

To the advance of the desert on areas once fertile, we may ascribe the decay of the great cities of Babylonia and Assyria, whereas the encroachment of tropical forest would seem to have choked out of existence the ancient civilization of the Mayas.

The historic period of man's life is, however, comparatively brief, and during that time no very vital changes in the distribution of rainfall, and consequently of vegetation, seem to have taken place

## XXVII. Human Life. Its Development and General Distribution

*Physical and political geography not distinct.* In the old books it was customary for geography to be divided up into water-tight compartments, namely, physical geography on the one hand and political geography on the other.

Physical geography treated of the Earth apart from man's influence and described in detail its features as now existent and the forces of Nature operating upon it. Political geography dealt with the Earth as a finished article, turned out by the hand of man, no attempt being made to connect this condition with the primitive one or to trace development from one stage to another. This left out of account almost entirely the facts that man's work has often been destructive, even from a utilitarian standpoint, as well as constructive, and that after all, in the first instance, and to some extent throughout, man's whole destiny has been shaped by the long, slow, relentless influence of geographical environment. 'Man has been so noisy', to quote Miss Semple, 'about the way he has conquered Nature, and Nature has been so silent in her persistent influence over man, that the geographic factor in the equation of human development has been overlooked.' This statement has been true till now, when every effort is being made to disentangle the distinctive influences of heredity and environment, and to place man in his true position in the scheme of things. In the light of modern science it is clearly impossible any longer to treat man and Nature as opposite and resisting forces. Man is truly part of Nature, and his work is most productive of results when carried out in harmony with her laws and seeking ever a wider and deeper understanding of them. In the remote past, more than in the present, man was in the grip of his environment, which determined his mode of life, his outlook, and even his religion. The manner in which he freed himself, yet always

remaining bound in essentials, is the whole history of human geography.

When we attempt to link up past and present into one continuous whole, we find that the early records are very scanty, and it is thus difficult to bridge over what has long been an ever-widening gap, namely, the interval which has elapsed between the time of man's appearance on the Earth and the stage the Earth had reached, through his influence, at the beginning of authentic history. The difficulty of clearing up the inter-relations of Earth and man is also greatly increased by the fact that research in this direction has been hitherto the work of specialists investigating along individual lines ; thus, the anthropologist has studied man from the point of view of evolution, i. e. man as a human being distinct from other living beings : the ethnologist deals rather with the different types of man and their differentiation into large or small groups with the distinguishing characteristics of each. History, also a science, is, properly speaking, limited to the time when man began to leave a written record ; there is, however, no definite boundary between the historic and prehistoric phase, as early records are mere scraps and fragments. Archaeology has to do with antiquities or any kind of relics handed down to us from prehistoric or early historic times alike. Sociology must also be considered, as elucidating the influence of man on men. It is the difficult task of the modern geographer to combine the knowledge of man, accumulated along these widely divergent lines of research, and to present it from an entirely new standpoint, namely, *the development of man in his environment.* This is geography in its broadest sense and links together in a natural way the various branches of the subject.

*Distribution of man.* In terms of biology man is an animal, and yet it is necessary to treat him in a category apart from other animals. He does not, like them, fall into an allotted biological province, but ranges throughout the region available for life and sometimes penetrates beyond it. This universality of habitat depends on two factors :

1. Man is a particularly adaptable being, some kinds of men being more so than others.[1]

2. Man, although of one species, is differentiated at the present day into well-marked races, and these are adapted in various ways for inhabiting different parts of the Earth.[2]

Man's distribution, then, is not affected by the boundaries of any animal provinces, for he either utilizes the animals he finds in each or imports those he needs. It is, however, limited, in the main, by the necessity of obtaining food, and therefore the rainfall map, which serves to show the extent of plant life, also fairly well determines man's limits.

To define this more clearly, the human life-zone, as Ratzel pointed out, is of varying breadth, lying between latitudes 80° N. and 55° S., thus roughly coinciding with the extent of vegetation on land. The zone is interrupted in places by two distinct natural barriers: (1) the oceans, (2) the deserts. Of the two chief oceans within these latitudes, the Atlantic alone produces a definite gap in the human girdle of the Earth, for the Pacific narrows greatly in the north, where its opposite shores are only fifty miles apart, and a broad band of habitable islands extends across the middle. As regards the Atlantic, on the contrary, the people inhabiting the Old World's western shores looked out for centuries on what they believed to be limitless ocean, and until the peopling of Iceland and the Färoes, there was no bridging of this gap, so that, in the region of the Atlantic, the belt of human occupation was broken right across.

*Classification of man.* The extreme mobility of the human species and its great variety have rendered the classification of its

[1] On the Panama Canal works there was great mortality through fever, until the employment of negroes, who were not so susceptible to it.

[2] The negro has pigment-bearing cells in the skin, and though we cannot say that these have been developed in order to enable him to endure the Sun's great heat, yet he is better able to bear it than the white man (see Ripley, *Races of Europe*, p. 468). The present writer also noticed that a Javanese, spending some months in England, became very much lighter in colour, approximating closely to the tint of a merely sunburnt European.

various types a difficult matter. Attempts in this direction have been made, however, from time to time, the groups being based on special characteristics such as differences in physical form and features, differences in language or in primitive culture. The modern tendency of ethnology is to classify according to variations due to geographical range, as is done in the case of plants and animals ; the earlier classifications are, however, convenient as forming broader groups. In following the geographical classification it will be noted that in course of time certain well-differentiated types of the human race have emerged and characterize definite parts of the inhabited Earth. On this fact was based the useful though rough classification made by Quatrefages, which distinguishes the white, yellow, black, and two mixed races, American and Oceanic. It is found to-day that other bases of classification, namely, hair texture, stature, head-form, &c., are more reliable than mere colour differences, and these are now utilized. It is, nevertheless, important to realize that children appreciate colour differences far more readily than others, and can easily grasp the fact that certain colours among mankind are characteristic of certain definite parts of the globe. For this reason the old colour classification should not be entirely abandoned.

*Heredity and environment.* It has been so far impossible to discover whether heredity or geographical environment plays the dominant part in directing the life and development of man. Certainly no other animal, no matter how favourable the conditions, has secured control over Nature in such a startling way, sometimes completely altering the face of the Earth to suit his ends. Wherever fairly potent changes have been brought about by other animals, such as the causing of floods by beavers or the formation of soil by earthworms, the effects produced, though momentous, have clearly been the result of accident and not design ; moreover, no one individual has arisen apart from his fellows to inaugurate such changes. These considerations point to the conclusion that environment alone cannot compass great ends, even upon a plastic nature, but that, probably, race differ-

ences account for the fact that some men emerge from the tyranny of surrounding forces and others do not. Nevertheless, many special features in distribution, &c., are unmistakably due to geographical influences, as, for instance, the centralization of the cotton industry in Lancashire owing to the favourable effect of the damp climate on the cotton.

*Human origins.* The main object of the present work being to develop the study of man in his environment, it is necessary before doing so to take a brief survey of his past history in the light of modern discovery with regard to it. Only in this manner can we appreciate fully the complexity of the struggle between heredity and environment, which has been going on through the ages since man made his first appearance on the Earth. The precise time at which this event took place is still a matter of uncertainty, but we know that man dates back at any rate to towards the beginning of the Pleistocene Period, the course of which was marked by alternating glacial and genial conditions.[1] At the very beginning of the Pleistocene Period or at the close of the Pliocene, 'implements' called eoliths occur, which some believe to have been made by a man-like creature, though some or all may have been produced mechanically by natural means.[2] The earliest man-like form known is that of *Pithecanthropus erectus*, found in Java, which is accepted by Keane as a possible human ancestor, and is of late Pliocene or early Pleistocene age. No further traces of man-like beings have so far been detected until the second interglacial period—perhaps 200,000–300,000 years later—to which period belongs a jawbone of sub-human type found at Heidelberg. The deposits of another 100,000 years or so have as yet revealed no actual trace of man except the Piltdown skull found in Sussex, in strata now ascribed to the third

[1] Four successive glaciations, with corresponding interglacial periods, have been traced in the Alps and Pyrenees. Further north the whole period may be merged into one owing to the mildness of the intervening climate being insufficient to remove all the ice.

[2] For an account of eoliths see Burkitt, M. C., *Prehistory* (Cambridge University Press, 1921). Recent discoveries of 'floors' at Foxhall seem to render the possibility of man's existence in Pliocene times tenable.

interglacial period.[1] The original owner of this skull, belonging to the genus *Eoanthropus*, may not be a direct human ancestor, as the lower jaw, which probably belongs to the skull, is ape-like. From about the second interglacial period onwards, evidence of apparently human activities becomes increasingly frequent in the form of flint instruments,[2] but no fresh relic occurs till the third (or some think the fourth) glacial period, in deposits of which the remains of Neandertal man were found. The skull and bones are definitely human, although differing sufficiently from the bony framework of a modern man to be classified as a distinct species of the genus *Homo*. The above extremely fragmentary record brings us to somewhere near the close of the Great Ice Age, when the more genial conditions of the present time were beginning to pervade the northern hemisphere. The ice-sheet, which had covered all the northern world and was flanked by dry steppe-like conditions in the central plains, now began to disappear, and part of the land surface became submerged by the water released from a state of ice. The region left by the retreating ice formed steppes, and forest invaded the central plains. The northern hemisphere thus became, in parts, more favourable for human subsistence, and Neandertal man in Europe seems to have been supplanted by new-comers, arriving possibly from North Africa, and consisting of more than one race,[3] but of definitely human type. From this time the reign of man on Earth may be said to have really begun, and recent archaeological researches are enabling us gradually to piece together the ages of his existence that have preceded the written record.

*Stages in development of human race.* It is now generally held

[1] The Piltdown skull may be as old or older than the Heidelberg jaw: see Keith, A., *Antiquity of Man*.

[2] The first flint implement, to be recognized as such, was found in London, associated with an elephant's tooth. This discovery took place in 1690.

[3] The most important race of late Palaeolithic times is the Cro-Magnon, a very much higher type than that of Neandertal.

Penck and Brückner date the coming of the newer type of (Aurignacian) man from the third interglacial period, which they consider was followed by a fourth glacial period, prior to the oncoming of more genial conditions.

that all mankind began, as it were, at the bottom of the ladder of progress, but that certain branches of the human race, in mounting it, far outstripped others, even as some individuals are bound to attain efficiency more rapidly than others.

*Classification of stages.* At the same time, the fact that in regions widely separated both in distance and in time the stages of culture follow the same general sequence, has made it possible to introduce a kind of classification by which the stage of advancement attained in any area can be established relatively to the rest of the world. Man's first and most vital necessity being to obtain food, one of his early instincts was to fashion implements for pursuit of game, and the nature of the weapon produced at the different stages of man's development has proved a useful index of human progress. The Danish archaeologist, Christian Thomsen, in 1836, first made use of this means of classification, which applies to most areas, although in a few cases some stages are entirely omitted, as for instance in Africa and Fiji, where there is direct transition from stone to iron.[1] The men of the Old Stone (Palaeolithic[2]) Age, whose weapons were of the roughest and most primitive kind, were succeeded by those of the New Stone (Neolithic[2]) Age, with whom the fashioning of implements became a finished art, so that in the end they were of the finest workmanship and beautifully polished. The next stage was marked by the discovery of the smelting of metals, when first copper, then bronze was utilized; the former giving its name to the brief and only locally developed Copper Age, which was succeeded by a long eventful Bronze Age. Following this, iron came into use, no longer as an ornament merely, but as a material for tools; and soon after this discovery, the historic period was ushered in. We find that although these ages can be followed in regular sequence, their duration varied in the most remarkable manner; thus, the Tasmanians at the time of their

[1] When Baron von Hügel first went to Fiji the inhabitants were culturally in the polished Stone Age; two years later they were using iron.

[2] The terms Palaeolithic and Neolithic, suggested in the first instance by Lord Avebury, are now in general use.

Some geologists distinguish an even earlier 'Eolithic Age'.

discovery were still in the Old Stone Age, as were also some Polynesians and the Australian aborigines. Moreover, the Neolithic Age endured in Scandinavia long after the Bronze Age had become established in the Aegean area. This way of classifying the stages obviously affords no clue as to why one kind of culture should have lingered so much longer in one region than another, but Morgan in his *Ancient Society* points out that the birth of a new idea, such as the smelting of metals, would have far-reaching consequences, even as, in a later age, the substitution of machinery for hand-labour transformed England from an agricultural to an industrial country. Morgan distinguishes three main stages in man's development : savagery, barbarism, and civilization ; and these, with the ideas that promoted transition, may be roughly classified as follows :

Civilization :
Transitional ideas : use of phonetic alphabet and production of literary records.

Barbarism :
- Upper Status.
  - Transitional idea : smelting of iron ore.
- Middle Status.
  - Transitional idea : domestication of animals (eastern hemisphere), cultivation of maize and irrigation (western hemisphere).
- Lower Status.
  - Transitional idea : invention of pottery.

Savagery :
- Upper Status.
  - Transitional idea : invention of bow and arrow.
- Middle Status.
  - Transitional ideas : fish subsistence and discovery of fire.
- Lower Status.

At the same time, what is known as the 'Bread and Butter School'—i.e. the classification according to successive modes of subsistence—is finding favour in America, and Morgan believes that, in the light of future research, this will ultimately develop into a more exact and suggestive method than those previously used.

For working purposes, however, the classification according to weapons is the simplest, and a good idea of it can be obtained from the following table, based partly on H. G. Wells's tables in *The Outline of History :*

| | B. C. | | | | |
|---|---|---|---|---|---|
| Early Palaeolithic. | 600000 | | | | |
| | 550000 | End of Pliocene Period. Beginning of Pleistocene. | | Eoliths | *Pithecanthropus erectus.* |
| | 500000 | First Glacial Age. | | | |
| | 400000 | Second Glacial Age. | | | |
| | 250000 | Second Interglacial Period. | | Rough, but improving, implements. | *Homo heidelbergensis* (perhaps later than *Eoanthropus*). |
| | 150000 | Third Glacial Age. | | | Piltdown skull. *Eoanthropus* (perhaps earlier). |
| | 100000 | Third Interglacial Period. | | | |
| | 50000 | Fourth and last Glacial Age. | | Good sole-shaped implements. | Neandertal Man (perhaps third glacial). |
| Late Palaeolithic. | 35000 | Steppe Period. | | The best unpolished stone implements. | Reindeer (Aurignacian) Man (perhaps third interglacial). |
| | 15000 | Forest Transition Period. | | | |
| Neolithic. | 10000 | Modern conditions. | | Polished stone implements. | Existing races. |
| | 5000 | ,, ,, | | | ,, ,, |
| Bronze. | 3000 | ,, ,, | | Implements (1) copper, (2) bronze. Gold used for ornaments. | ,, ,, |
| | 1000 | ,, ,, | | | ,, ,, |
| Iron Age. | 500 | ,, ,, | Scandinavian: Pre-Roman. | | ,, ,, |
| | 0 | ,, ,, | Scandinavian: Roman. | | ,, ,, |
| | A. D. | | | | |
| | 400 | ,, ,, | Scandinavian: Post-Roman. | Age of gold. | ,, ,, |
| | 800 | ,, ,, | Scandinavian: Viking Age. | Age of silver. | ,, ,, |

It must, nevertheless, be borne in mind that the time-periods, although correct relatively to one another, are based on very slender data and are in the highest degree hypothetical, also that in Scandinavia the withdrawal of the ice was later than elsewhere (*c.* 10000 B. C. ?).

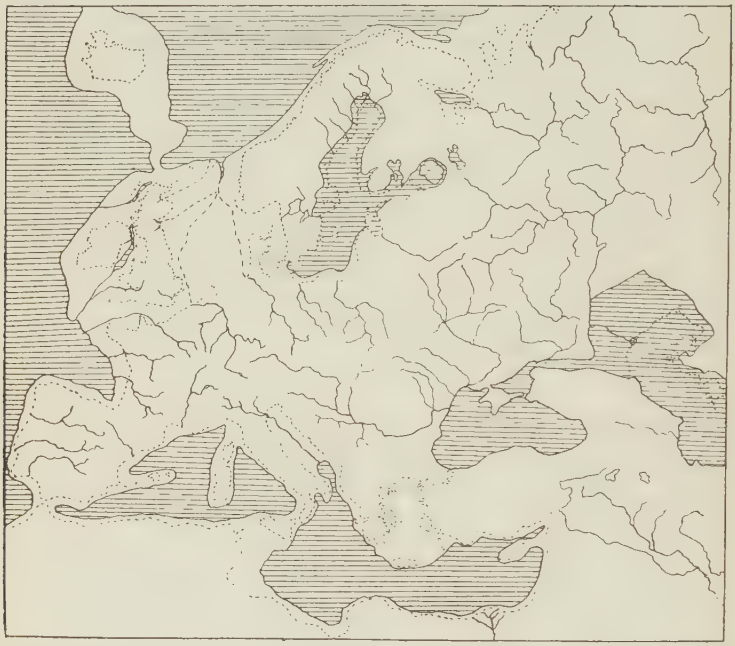


Fig. 128. Conjectural Configuration of Europe in late Palaeolithic Times (35000–15000 B.C.?), showing land-bridges by means of which True Man may have replaced Neandertal Man in Europe. Notice that the North Sea at this period probably formed the basin of a large river. The area under water in the Caspian depression is quite hypothetical. (Partly based on maps of Professor James Geikie : see *The Antiquity of Man in Europe*, Oliver and Boyd, Edinburgh, 1914.)

*Man in his environment.* Having now a fairly clear general notion of man's origin and early development as far as they are known, the next step is to place him in his environment and to consider in detail his relationship with it.

Supposing that, towards the close of the Ice Age, the ice was gradually withdrawing, until it took up almost its present position,

and the steppes, receding northward after it, gave up their ground to forest, the conditions of rainfall and vegetation, over the greater part of the continental surfaces, would become roughly similar to those now obtaining. The accompanying map (fig. 128) shows the conjectural outline of Europe and part of Asia, in the transitional stage, when the water, released from the ice, is gradually refilling the basins of the North Sea, Baltic, and Mediterranean, converting the latter from the condition of two separate lake-basins into an inland sea. It is important to note the existence of land-bridges between North Africa and Europe, as these may have had an important bearing on the earlier movements of mankind, just as the closed ring of the Pacific on the north invited migration from what is now one great isolated land mass to another. Considering the availability of the world as a whole for human occupation, we see at once that some regions would support life easily, others only with difficulty. Early man being a primitive creature whose needs were mainly animal, it would seem fair to assume that he established himself first where the conditions of life were simplest,[1] and whether he flourished or not depended on the extent to which he was capable of utilizing the natural means of living at his disposal. As the number of individuals increased and more space was required, less advantageous regions would be invaded. In the early days of the human race, therefore, man's destiny was largely shaped by his physical surroundings, and from his standpoint the habitable portion of the globe divided itself into two main regions according to the vegetation, i. e. forest-lands and grass-lands.

*Type of regions available for occupation.* Both of these types of regions were ripe for man's occupation ; in the former he could gain his livelihood as a hunter, in the latter either as hunter or herdsman, and wherever the prevailing conditions, as distinct from man's influence, were powerful enough to hold their own against him, he still remains subservient to these ; that is to say,

[1] In the Old World the higher cultures were practically confined to the North Temperate Zone, approximately 24° to 50°, or in the extreme west to 55° ; in the New World, owing partly to altitude and other influences, the highest cultures were almost completely limited to intertropical regions.

in the tropical forest and prairies he is a hunter still and in the steppes a herdsman, in spite of his conquests over Nature elsewhere.

The conditions of life in the tropical forest (fig. 129) are not easy to bring home to the mind of the ordinary dweller in towns. He must paint for himself a picture of densely matted boughs, veiling the sky so closely that dim twilight prevails even at high noonday, and producing a colour scheme at once sombre and monotonous, broken here and there by splashes of bright colour, due to a gaily-marked tree-stem or the light shining through an opening. Except for the banks of rivers or the edges of clearings, gay colours are relegated to the topmost branches, where the birds and butterflies seek out the flowers and fruits. Narrow forest-paths made by wild beasts, or by the scarcely less wild human races, may be followed ; otherwise a mile's advance during the day may be considered good progress in cutting a jungle-trace. Human life in such a region has altered little since the earliest days of man's occupation of the Earth. The climate encourages indolence and needs are few, for an abundance of food is obtainable without effort and the requirements as to clothing and shelter are at a minimum. Enterprise in these regions is of little avail, for the forest presents an impassable barrier to progress on every side and, even if a clearing is made, the jungle quickly steps in again and claims its own.[1] The extent to which

Fig. 129. Tropical Forest in the Congo State.

[1] See Rudyard Kipling, *The Letting in of the Jungle.*

the power of the forest dominates the mind of man is borne out by the expression 'May a tree fall on me!', the strongest asseveration of the Malayan aborigines.[1]

In the primaeval forest, man perforce led the life of the huntsman, supplementing his food with the fish from the rivers and with wild berries and roots. In some cases, as in those of the pygmies of the Congo forest zones, the Sakais in Malaya, &c., this wandering life has continued up to the present day; in others, as in the case of the Papuans, further developments have taken place; the people have adopted the idea of having fixed dwellings and have established themselves in communities. These concentrations, however, are few and scattered, and extend mainly along the river banks. The men are still engaged in hunting and fishing, but the women, having a fixed abode, carry on a small amount of agriculture, to the extent of selecting plants useful for food and clearing out others or even, at times, planting a few crops and letting them grow of their own accord. Practically the only method of intercommunication in such a region is by rivers and streams, and by means of these waterways a certain amount of barter is carried on, so that the few external wants of the people can be supplied. The conditions of such a life are uniform throughout long periods of time, and afford therefore no stimulus to mental growth or advancement; Nature presents no new problems, nor does she enforce removal by cutting off supplies, consequently the people remain in a primitive state and are practically without history.

*Human life in the temperate forest.* Not so is it with the temperate forest regions, once of vast extent and similarly inhabited. Here the conditions of life were never so easy, for, even when the ice-sheet had receded, man must still have suffered from cold and the need of shelter, this latter having sometimes to be shared with or reclaimed from wild beasts who made the caves their homes.[2]

It seems as if, in such a case, the pains and perils of existence

[1] For description of tropical forest see Skeat and Blagden's *Pagan Races of the Malay Peninsula*, given in Bibliography below.

[2] See specimens from Kent's Cavern in Torquay Museum.

must have supplied to those capable of advancement the necessary stimulus, as at the present day we find but few wide stretches of temperate forest inhabited by forest dwellers. The clearest case in which environment has played a winning hand against race is seen in the case of the Tunguses, the greater part of whom now form the agricultural and town population along the Amur River and its fertile side-valleys. The same race is represented by the fishers on the Arctic coast, while a few still survive as hunters in the East Siberian woodlands.

Fig. 130. A Portage in the Canadian Coniferous Forest.

It is true that considerable stretches of land in the temperate zone still remain afforested, as in the north-west of the North American continent (fig. 130), but here the original inhabitants proved incapable of responding quickly enough to advancement, and gave way before the influx of a more vigorous race. A great many were removed to reservations, but at the same time there was a considerable intermingling of race between the aborigines and the European usurpers. The latter, however, predominated, so that the occupations of hunting, trapping, and fishing have yielded very largely to lumbering; thus does the modern life of cities reach out and tighten its grip on the remotest wilds.

The greater part of the temperate forest region has been completely transformed by clearing, and in this way vast agricultural operations have been rendered possible. The great central plain of Europe, for instance, retains its forest character in isolated patches only, so that the former hunting-ground of the bear, wolf, fox, beaver, &c., is now mapped out into neat squares filled with plants for man's immediate use, or else is covered with a network of ways leading into and among great blocks of human habitations.

Fig. 131. Fortified camp on hill-top near Malvern—probably British. These camps occur very frequently along the Welsh borders.

In our own country the change made in this direction has often completely altered the face of the land. Once, seated on a little knoll outside Lyme Regis and looking out over the undulating hills of Dorset, the present writer, being allowed to peep through the magic glasses of Professor Boyd Dawkins, saw the country as it was when our early fathers hunted and fished for bare existence. A dense forest filled the valleys, the courses of the streams were wide and swampy with the tangled undergrowth, only the hill-tops were fairly clear, and here man dwelt, safe at once from foes of his own kind and from the wild beasts lurking in the forest depths. In the time of our ancient British forefathers the hill-tops still served as camping-grounds, and the

great earthworks around them bear evidence of their last desperate stand against the advancing tide of Roman overflow (fig. 131). In many cases the same camps were strongly reinforced by the conqueror.

Such was the life of the temperate lowlands, always difficult owing to the alternations of seasons, which afforded a precarious livelihood in summer, but gave little chance of life in winter to those who did not think ahead. The absolute necessity for thrift and forethought was always a stimulating influence in these latitudes, where the very climate inculcated vigour in a responsive race; consequently, when clearings were once begun they spread quickly, intercourse between the various parts of the country then became easy, and knowledge gained in any part permeated the whole region. Thus it is that the temperate forest lands retain only the remotest traces of a primitive existence and differentiation has here reached its highest development.

*Human life on grass-lands.* Outside the region of tropical forest, the luxuriant vegetable growth, owing to diminished rainfall, gives way to vast park-like stretches of land with fewer trees, merging into actual grass-land. These are the savannas, which touch on the equatorial forest on the one hand and, on the other, owing to the drought of the trade-wind belts, graduate into deserts. Beyond the desert region again, at a low elevation but a higher latitude, and consequently with a great climatic range, are the steppes, somewhat similar in nature to the savannas in their influence on human life. Both steppes and savannas are characterized by the fact that the vegetation in them is of short duration, growth extending in many cases to a few months only, drought being prohibitive to active plant life during the remainder of the year. The principal plants that can stand this treatment are grasses, the greater number of which carry through their life-cycle in a few months, and geophilous plants, which have bulbs or tubers capable of surviving long periods of drought.

In regions such as these, man, as a huntsman, is at a disadvantage, for the animals are wild and nimble, the grass affords little cover, moreover his erect position makes him a conspicuous object. Hence, hunting in the grass-lands brings little success,

and the bushmen who represent this type occur in ever diminishing numbers. In the eastern hemisphere, however, man very early adapted himself to the grass-land conditions in quite a special way, namely, by domesticating herbivorous animals, which he used for food. Thus arose in the steppes a population of nomads, who made a livelihood by cattle-rearing. The peaceful nature of this occupation and the experience of life gained by constant movement seems to have encouraged intellectual

Fig. 132. The Palestine steppe region in Spring.

development of a kind, in spite of the endless monotony of the surrounding conditions of life (fig. 132). A recognition of the closeness of the family tie made greater success of the herdsman's industry possible, hence the patriarchal idea prevailed, and the importance of children was fully recognized. So vital was this need that polygamy was the rule, and the head also attached to himself several other families in a state of servitude. Although the wants of the nomad were few, and such as his flocks and herds could directly supply, yet wealth, as counted by head of cattle, was of great moment to him. The kind of civilization thus produced is exemplified in the lives of the patriarchs, who early enforced the recognition of a high moral code and the

acceptance of a monotheistic religion. This type of the human race is best seen in the steppe regions, for these are of vast extent, and merge into the temperate forest belt, where the development of culture has been most rapid.

Certain parts of the temperate grass-lands, such as that traversed by the great rivers of Russia in their lower courses, are peculiarly favoured as regards soil, and are then even better adapted, than are the cleared expanses in what was once temperate forest, for the cultivation of special grasses, such as wheat. In a region like this, agriculture predominates in Old and New World alike, but under very different conditions. In the Old World, where the industry has arisen naturally, it is carried on by the people who have inherited the soil, and with it their primitive methods of husbandry, whereas, in the prairies of the New World, agriculture has been developed artificially by settlers, who have established themselves in the region for that special purpose, and have imported with them, as far as possible, any outside knowledge existing on the subject.

*Life in the savanna.* The savannas, or intertropical grass-lands, differ from the steppes in having a less favourable environment (fig. 133). Being in touch, on the one hand, only with the backward peoples of the equatorial forest, and merging, on the other, into the almost unpeopled desert, their populations have little outside stimulus to intellectual advancement. The climate, moreover, fosters indolence, for need of shelter and clothing being slight and easily supplied, there is not, as in the case of the steppe-dweller, any necessity for sustained effort. Nevertheless, man in these regions is found to be more intelligent than the adjacent forest-dweller, and shows possibilities of advancement, which in some cases are being realized. The occupations here are similar to those of the temperate grass-lands, but differ in the New World and the Old ; in the latter they are agricultural and pastoral, in the former hunting or agricultural. In the most typical development of this kind of region, that of intertropical Africa, north and south of the forest-belt, the agricultural communities near the forests are mostly small and limited to the village and its headman ; the pastoral communities are patri-

archal, and have a well-defined political system under a feudal chief as ruler. Some of these tribes cherish the tradition of having formed the elements of extensive empires, such as the Zang Empire of the twelfth century, which extended traditionally from Somaliland to beyond the Zambezi, the Kitwara Empire in the region of the Great Lakes, and the mythical Monomotapaland from the Zambezi southward.

FIG. 133. A station in the savanna country, North Australia.

The Dekkan of India represents a specialized type of agricultural savanna, its extensive nature being due partly to the richness of the soil and partly to the survival, in a limited degree, of an ancient civilization.

We have thus seen that, as far as we can trace the early history of man, he has developed along two chief lines, corresponding to the two main distinctive types of vegetation, namely, the forest and the grass-lands; also, in the temperate forest lands more particularly, development, if possible to him, was stimulated by the incoming of different conditions as the forest was gradually swept away. It is easy to guess that progress would be made in these regions first, for, on the one hand,

life was very arduous and difficult and, on the other, the forest was amenable ; in the tropical forest to effect widespread clearings would be impossible and quite useless labour.

*Continuity of biosphere.* As regards these two main types of life-zones, it is not quite accurate to say with Ratzel that they are actually interrupted by the deserts and by the oceans which act as water-deserts. The forest-dwellers, especially those of the Pacific Basin, are more or less linked up with one another, in spite of the intervening waste of ocean, by the island-dwellers ; a broad belt of forest is, for instance, strung out from the mouth of the Ganges to the eastern limits of Polynesia. Although the origin and earliest stages of the island-peoples are little known, there seems to have been intercommunication of some sort in very early times, as is indicated by Prof. Elliot Smith's map of the Heliolithic culture (fig. 137), even if, at other stages, this may have been broken temporarily or have ceased throughout long periods.

Dry deserts are also quite ineffective in prohibiting intercourse, for even the far-flung cold desert of the north, although it has no oases, merges gradually into temperate forest region southward and is throughout interpenetrated by the ocean, the margins of which teem with animal and, for a short season also, plant life, thus rendering supplies available for hardy wandering peoples.

*Desert life. The oasis.* The park-like savanna passes, also quite gradually, into the hot dry desert, which is itself punctuated by fertile oases (fig. 134). The oasis, which constitutes the only part of this desert available for continuous habitation, is in itself comparable to the island of the tropical ocean but is insulated, not by water but by land, resembling in fact the other stage of Gideon's fleece. Oases owe their position and existence to the presence of wells, springs, artesian wells and watercourses, emphasizing to us the fact of the immense possibilities of a region where water only is needed to make it blossom as the rose.[1] The vegetation that has clustered for ages round these

[1] Implements collected by Captain Cortier, now in the Paris Natural History Museum, prove that both in Palaeolithic and Neolithic times the Sahara was in many parts densely populated, and so was not then in a desert condition.

wells has supplied in its rapid growth and decay the soil needful for agriculture, and the comparative ease with which a livelihood is obtainable in these regions has probably been in the past the determining factor in attracting quite a considerable population hither. Since the initiation of commercial interrelation between peoples, the importance of many oases has been greatly

FIG. 134. A village in the Sahara. Note the presence of palm-trees indicating the oasis, also the stony desert in the foreground and the sandy desert behind.

enhanced by the streams of traders passing through from one rich trading country to another.

Life here is similar to that of the steppes, being more or less nomadic, but many of the people remain settled in the different oases and carry on agriculture, which is rendered easy owing to the extreme fertility of the soil, from which the soluble salts have not been removed by rain.

The oasis-dwellers constitute an example of the particular form of human society held together by a patriotism based on religious feeling. This form of patriotism, classed by Demolins [1] as the

[1] Demolins, Ed., *Anglo-Saxon Supremacy, to what is it due?* (Leadenhall Press, 1898).

most primitive, prevailed already when Assyria and Egypt emerged from the desert as the first great oases of history, and was later adopted as part of the administrative system of Islamism. The Brotherhoods or Zaiouahs (Zawias), which characterize the system, form a complete network linking together the various oases, and are so numerous that, in the oasis of Guemar alone, there were, for a population of 700 or 800, as many as twelve mosques and four zawias. This particular form of religious feeling is based on fear rather than conscience and, in times of unrest,

FIG. 135. The Siberian tundra.

amounts to frenzy, quite uncompromising and utterly pitiless. At such times there usually arises a Mahdi who rouses the people to fanaticism and is looked upon as a direct emissary of God. The power of the Zaiouah permeates the whole life of the people, rendering certain parts of the desert actually more difficult of approach than is warranted even by natural conditions, so that, as Mrs. Rosita Forbes[1] discovered when on her way to Kufra, the stronghold of the Senussi, any traveller not journeying with the sanction of the Brotherhood goes in peril of his life and has little chance of reaching his destination.

*Life in the cold deserts or tundras* (fig. 135). The cold deserts have a very different influence on their population. Instead of being on a well-marked trade-route between rich countries they are on the

[1] *The Secret of the Sahara* (Cassell & Co., 1921).

very fringe of the human belt and are reached from the populous world-centres rarely and with difficulty. In the short summer season the ground is well watered, but only plants with a very brief life-cycle can survive, such as barley or rye; otherwise reindeer-moss provides abundant pasturage for reindeer, but very little else can be grown. During the summer the rivers abound in fish and the ocean shores teem with abundant life, and much has to be done in the way of storing both fish and reindeer-meat in order for it to be possible to support life during the winter. A nomadic life is necessary because of the need of finding enough food for the reindeer. The people are simple and primitive and their life is hard, so they have little time for intellectual pursuits.

*Recapitulation of early human types.* Summarizing once more, the above sketch of primitive man's distribution shows that he developed along somewhat different lines in accordance with the characteristics of the vegetation zones. Referring again to the diagram of the vegetation belts, we have man in:

(*a*) the tropical and (*e*) the temperate forest;
(*b*) and (*d*) the grass-lands;
(*c*) the hot and (*f*) the cold desert.

It seems probable that the two types, i. e. those of forest and grass-land, developed first, and that human life gradually invaded less favourable regions as pressure from within necessitated movement outwards.

It is important to realize that, just as gas within a bottle appears at rest to our gross perceptions and yet we know that its particles are in constant and rapid motion, perpetually bombarding the walls of the vessel that contains it, so man, and also the rest of nature, are in a perpetual state of flux and can only be broadly designated as occupying this region or that.

*Human life on coasts and islands.* Thus far the vegetation zones only have been considered in connexion with man's distribution, but the proximity of coast-lines is another important factor. The dwellers on coasts have an additional means of obtaining food, namely by fishing, and man soon ventured in hollowed-out tree-trunks in order to increase his fishing facilities.

The case of island-dwellers is somewhat similar, but these have a feeling of additional security from the fact that they are protected by the ocean from outside invaders. They usually show enterprise in early devising means of communication with other lands,[1] but their existence is sometimes cramped by the need of various almost necessary things, such as useful animals, &c.

*Occupations of primitive man.* We have seen, from the above sketches of the development of human life in the various regions, that clearly the most primitive condition is one in which man has to expend most of his time and ingenuity in obtaining food. Thus, primarily, he was a hunter or a fisher. In very early times, however, certain occupations, indirectly connected with obtaining food, were engaged in: for example, cattle-rearing and husbandry. In the former, the necessity for a wandering life still prevailed and so further developments followed but slowly; in the latter case, the sedentary life soon led to further changes and adaptations, so that differentiation took place rapidly.

In the early stages of man's development, the vegetable world furnished him with means of producing fire, of constructing shelter, of fashioning garments, and also of obtaining nourishment easily, so that, on the whole, where there is a rich and abundant plant life, man is not stimulated to effort and consequently does not of necessity advance in civilization. For those capable of advancement, on the other hand, it offers boundless resources. In primitive countries, as also in ancient times, an abundance of vegetation hinders advancement for another reason, namely, that man is brought up short against a wall of impenetrable forest, which he can only traverse by following the tortuous courses of the streams and rivers wandering through it. Even to-day this is still the case in regions such as the Amazon's banks,

[1] The aboriginal Tasmanians, who were considered to have reached the Middle Palaeolithic stage of culture, had devised rafts in which they could adventure themselves as much as three miles out at sea.

In the regions of Oceania, the islanders when discovered had reached a high level in the science of seafaring, and extensive migrations seem to have taken place, although only the Stone Age of culture had been reached.

so much so that no one quite knows whether Mr. Roosevelt's river had been previously discovered or not. Not only this, but intercourse with the plant world seems to have less effect in stimulating the mental faculties of man than does a close association with animals. The forest men are, even now, backward in civilization, whereas in very early times the wandering herdsman exhibited signs of intellectual refinement. It is still in the tent of the nomad that the art of weaving, for instance, attains its greatest development, for skill in formulating design and in blending colours demands artistic insight of the highest order.

Thus, the occupations of man in his primitive state depend on the influences of his surroundings, chiefly those of climate and vegetation. As time goes on, however, man learns to turn natural conditions more and more to his advantage, and, after felling or burning the forest, he establishes himself as an agriculturalist. Still later these more primitive occupations become subordinated to a host of others, arising mainly from the massing together of individuals in consequence of man's gregarious instinct.

*Effect of the massing of individuals.* The immediate result of gregariousness is to increase the struggle for existence and hence to promote division of labour. The first division of this kind was made between the work of the sexes. The man's work being that of obtaining the food—a strenuous occupation which required much time and skill—woman was left to erect or take down the tent, prepare the food, and fashion whatever was requisite by way of clothing.

The massing together of individuals soon led to a multiplication of needs and the primitive occupations became, in time, subordinated to a variety of others, so that still further division of labour became necessary; this fact, if accompanied by the power of absorbing or evolving new ideas, gradually tended to civilization. Civilization in its intensity seems to have developed sporadically and usually in small communities. If these communities were in contact with the outside world, the civilizing process continued until it leavened the parts in touch with it, as in the case of ancient Greece. When there was little or no outside intercourse, the civilization advanced to a certain point only and then crystallized,

so that, if adjacent lands subsequently became civilized, the first civilized people appeared backward in that respect, as was the case with China.

When once civilization has taken hold, man's destiny, broadly speaking, ceases to be necessarily shaped by his physical surroundings for he, having assumed greater control both of himself and them, and possessing wider knowledge, moulds his surroundings to his will. This is accomplished more or less successfully according to their plasticity and to the degree of civilization he has attained. At the same time, the stage of civilization reached in any region is an outcome of the surroundings also as, if conditions are such as to admit of a simple and definite solution of the problems of subsistence and defence, a state of equilibrium is soon attained and alien ideas are not encouraged; if, however, these conditions are unfavourable to the solution of such problems, new ideas carry weight and an acceptable one may, by offering a new solution, produce rapid changes probably in the direction of advancement.

*Areas of concentration.* The first unmistakable sign we have that civilization has actually taken hold consists in the massing of individuals in certain areas, or it may be more true to say that, wherever concentration for some cause has occurred, there civilization may be found, for mind reacts on mind and it is in the crowded community that the new idea most commonly originates. When the ancient hunters first contrived to eke out a precarious existence on the borders of the receding ice-sheet, families must have been few and widely scattered; but conditions were improving and, when the curtain rises again on a new race of hunters—in the Old World, at any rate,—life was far less hard and the concentrations of population in certain favoured regions had already begun. The idea of cultivating crops, which originated perhaps in the careless casting away of seeds after a meal of fruit, was one of those whose far-reaching results were destined to lift man a whole stage on his way towards civilization. In the Old World, where the presence of animals amenable to domestication had already supplied a stimulus to advancement, this idea took hold rapidly and the fertile banks

of rivers offered conditions highly suitable for cultivation. Concentration on river-banks constituted then the first phase in cultural advance, and history opens with the brief and scattered records of the somewhat specialized civilizations in those areas. Later phases of human development are also connected with water; in fact it may not be a great exaggeration to say that the guiding lines of the world's history have been shore-lines.[1] Prof. Myres, in his little work on *The Dawn of History*, sums up the four phases which the concentration process has successively assumed. We thus see that the main stream of the world's history, as we know it, has shifted from one type of shore-line to another, but we must not fail to realize that during its flow it has impinged upon and, at times, intermingled with countless other streams which, for the purpose of our present survey, we are bound to disregard.

Before describing these four phases it is pertinent to mention that the whole conception is similar to that of civilization phases, which was first adopted by Böttger [2] in describing the historical development of the Mediterranean Basin itself, but Böttger's four phases differ from these in being based on peoples and not on environment. He does, however, recognize incidentally the second and third phases of Prof. Myres's work and represents them graphically thus:

Mediterranean : Atlantic = Europe : Asia

with the remark that, by combining the two outer and two inner members of the proportion, we get the two civilizations, ancient and modern, and that the relative positions of sea and land are identical in both, i. e. the land faces towards the sea on the west. In a note on p. 375 he draws a 'Phantasiegebilde' of a future fourth phase, when the main culture-centre will have shifted still further westward and when, upon a still broader ocean bosom, the storm-tossed nations, after thousands of years of strife, may find peace at last.

[1] First of rivers, later of seas also.

[2] Böttger, C., *Das Mittelmeer*, Leipzig, 1859.

## XXVIII. Special Phases of Human Concentration

*Four phases of concentration.* The four phases of concentration are :

1. That of alluvial river-valleys, mentioned above.

2. That of the dwellers on the encircling shores and adjacent islands of an inland sea. The Mediterranean is the most striking example of this, as for centuries the world's history was mainly fashioned upon its shores, but the Baltic, the Gulf of Mexico, the Malay Archipelago, and the Japanese islands with Korea also furnish examples.

3. A phase of more aggressive seafaring, when need for expansion, advancing civilization, and improved shipcraft caused the races of the land-locked sea to burst beyond its confines and to compete with others outside it for foothold on the ocean's wider shores.

In this Atlantic concentration, the shore-dwellers from both the inland seas of Europe took their share. The Mediterranean outward movement, which was partly a peaceful penetration and partly conquest, originated in a small degree with the Phoenicians, who might in this connexion be called the Vikings of the South ; the later Baltic movement consisted in a long series of conquests and extended even into the Mediterranean itself. This phase included, later still, the crossing of the Atlantic by bold adventurers and the subsequent bringing into subjection of its entire encircling rim.

4. The fourth phase shows a still further shifting outward and westward, involving the shores of an even greater ocean and including the colonization of Australia, the leap into modernity of Japan, and the linking up of commerce by means of the Panama Canal.

It must not be supposed, however, that these phases are participated in by the peoples of the whole world, as they involve only the movements of those races whom we may call the ' makers of history '. In other parts of the world, developments have also taken place, but changes there have been slow or interrupted by

long periods of quiescence, so that what history there was, tense with interest as it may have been, has faded out of memory. This is the case with many civilizations, such as those of South and Central America and the Mound-builders of the Mississippi valley; others, again, still persist in modified form, such as those of India and China.

The scope of the present work is, however, not history but geography, so all we have to do is to consider typical cases, where environment has played a really significant part in the establishment and development of peoples.

*Typical regions of non-concentration.* We have shown above that there is a great tendency for the massing of population in favourable areas, but environment also plays an obvious part in preventing this massing from taking place in unfavourable ones, such, for instance, as mountain districts. Here, as seen in the Swiss and Tyrolese peasantry of to-day, the life still faintly resembles that of the steppe-dwellers. The people live isolated in families and are nomads in so far as their dwelling varies according to the season. In summer they follow their cattle into the high grazing pastures of the mountains, in winter they usually carry on some industry in the town or village below.[1] There is little division of labour; each man builds his own chalet, feeds and looks after his cattle, grows his own crops, including flax and hemp which, with the aid of his women, he makes into linen or rope. Contrast this simple bracing life with that of the vast population massed on the Belgian coalfield, attracted thither primarily by the discovery of the value of coal and secondarily by the fact that, where many individuals give their time to one definite occupation, division of labour is a necessity and so gives rise to many others. A thrifty and hard-working people, the Belgians are accustomed to comfort and find it hard to realize that happiness can be attained without it.

These two instances are given as illustrating two rather opposite types, which in modern times seem to have evolved from the strongly marked contrast in surroundings between the

[1] The host of the Dammergletscher Hotel in Switzerland, in the year 1900, was a hatter by trade in winter and had a shop in the town below.

somewhat hard and difficult life of the highland and the easier conditions in the more wealth-yielding lowland.

The centralization of population in its earliest stages shows many signs of having been initiated in the fertile valleys of rivers, and consequently in the plains and lowlands.

*River-valley concentration. The Nile.* The earliest well-known example of river-valley concentration is that of the Nile Valley, which was peopled in Palaeolithic times and to which a very early civilization is traceable. This civilization seems to have had its origin in Neolithic times, as even then symbols were used to designate individual property, thus foreshadowing the art of writing. The first dynasty of Egypt, which may date back to nearly 5000 B.C., seems to synchronize approximately with the earliest indications of civilization in Crete, as pottery of possible Cretan workmanship has been recognized on early sites in the Nile valley.

Somewhat isolated by desert from the rest of the inhabited world, Egypt developed a distinctive culture and left a marvellously complete record of its history, not only in inscriptions but in artistic products of the most perfect kind. This isolation, however, was not complete, as a certain amount of intercourse seems to have developed on the one hand with Babylonia, and on the other with the Aegean. The interchange of ideas, promoted by these outside relationships, has linked up the two river-valley civilizations, i.e. those of the Nile and Euphrates, with the areas of later and wider development, unlike those of the Ganges and China, which did not join the main stream, but remained apart.

*The Tigris and Euphrates.* Another area of human concentration, which developed perhaps even earlier, but has left less complete records, was in Babylonia, situated on the joint delta of the Tigris and Euphrates. Here, owing to the configuration of the region, the population was more centralized than in Egypt, and the land, though extraordinarily fertile, was subject at times to uncontrollable floods. For this reason, any buildings that were intended to last, such as temples, were built on platforms raised above the flood-level.

Owing to the dense population, the industries did not remain

purely agricultural as on the Nile, but manufactures such as weaving became established. Moreover, the inhabitants of the region, being able to carry on intercourse with peoples outside, soon developed an important trade and Babylonia became a great centre of commerce. While the peaceful people of the lowland valley flourished, so also did the wilder and more predatory nomads of the upland regions outside. These overflowed into the lowlands from time to time, ousting the original inhabitants or establishing themselves side by side with them. Thus Babylonia continued its history under a different rule, and the same people, spreading outwards from it, established various cities along the banks of the twin rivers. Early in time, a rival empire, that of Assyria, was founded on one of the large side-streams of the Tigris, equally amenable to cultivation. This empire, absorbing at first the whole of Babylonia, was later overthrown by it and the kingdom of Babylon re-emerged. The valley of the two rivers, however, long continued to rouse the lust of the conqueror, and the whole region fell a prey to each rising power in turn: Media, Persia, and for a short time, Greece. Its later history contains nothing but a long record of decay due, in part, to neglect of irrigation and perhaps also to increasing desiccation. During its period of prosperity, the culture of the twin rivers came into contact both with Egypt and with Greece, and thus exercised a direct influence on the development of civilization.

*The river-valleys of China.* Another typical river-valley community dating from remote antiquity is that of China. Here the population ranged first along the Hwang-ho, but the disastrous floods of that valley caused concentration to become effective finally in the Yangtse-kiang valley, which is not similarly troubled. Undoubtedly the first period of man's occupation in this region was one of hunting and fishing, but the establishment of settled agricultural industries early succeeded, as already in the twenty-eighth century B. C. we hear of an emperor inventing agricultural implements and being acquainted with the medicinal properties of herbs. From the bare fact of an emperor's existence we may argue that there must already have been a very considerable population in the district, and the study of medicine is not a

barbaric pursuit. The literature of China extends back to 1800 B.C., and we cull from its fragments that the population was not only agricultural but also commercial, producing silk, silk stuffs, fine furs, &c. Thus a high stage of civilization was early reached, but too early and in too isolated a region to affect or be affected by the main stream of human progress, which is only now beginning to flow towards the Pacific shores.

*The river-valleys of India.* The north of India furnishes another striking example of river-valley settlement. Tribes of wandering herdsmen seem to have invaded the Indus valley from the north and gradually spread from the Punjab, where they first settled, into the valley of the Ganges as far as its southward bend. Although cattle-grazing was their original industry, yet this gave way by degrees to the settled life of the husbandman, and the people soon established themselves in villages and towns on the river banks. Thus, in later times, we find the Ganges valley became the valley of large cities. An account of this people is given in the Rig-Veda, which is believed to date from 1400 B.C. The early hymns describe the warlike tribes of the north-west marching in communities from one valley to another with their wives, children, and cattle. Later we hear of an acquaintance with metals and the existence of various craftsmen, all this occurring before the lightning-like conquest of Alexander, the effect of which is further discussed below, p. 329.

The river-valley settlements above mentioned are not only the most important ones from the cultural standpoint of the ancient world, but those which, coming eventually into contact with other civilizations,[1] have also left a lasting influence on the history of mankind. Being isolated in great part from one another, each developed a specialized culture, which had advanced far on its own lines before it became subjected to influences from without. The study of these ancient civilizations is a revelation, not only on account of their divergence from one another in many points, but also because of their amazing similarity in others;

[1] For example, Egypt, which was itself influenced by Babylonia and probably Crete, but the early stages of Greek art appear to be dominated by it (see early examples in the Archaeological Museum at Cambridge).

and still more owing to the fact that many principles, deas and modes of thought are, apparently, identical with those of the present day.

*Second Phase. Inland-sea concentration. The Mediterranean.* Having now described the most typical cases of concentration in river-valleys, we next pass to the second phase of human-life development, that, namely, of the dwellers on the encircling shores and numerous islands of an inland sea. The Mediterranean is a deep tideless stretch of water extending east and west in the most climatically favoured part of the world. A study of its early history shows that, in late geological times, it originated through the flooding of the basins of two large lakes, which formed the western part of a huge chain of lakes, stretching from Gibraltar perhaps even to Lake Baikal. A land extension southwards of Italy and Sicily would separate the basins of these lakes, the western one being rounded off by a land-bar connecting the two Pillars of Hercules. The existence of land-bridges [1] between Africa and Europe removes certain difficulties we should otherwise have had in accounting for some early phases of human distribution ; it may also help to explain the individual development of the eastern and western basins.

The Mediterranean Sea certainly owes its early cultural development to the fact that it is a water- and not a land-area, for land surfaces in this region tend to suffer from drought, just as in Asia the corresponding area is largely desert. As sea, its entire shores receive a sufficient rainfall, enabling the inhabitants to profit to the utmost by the soil's fertility. The mountains being near the coast, the slope is sudden and the rivers swift, consequently much material is liable to be washed away. This difficulty can be partly met, however, by terracing, and the many sunny slopes offer compensation for the sparsity of soil, rendering life, on the whole, simple and easy. The wide east and west extension of the sea have caused it to become a most important maritime link between distant lands, and it has provided a water route by which, before the development of land routes, the

[1] See map of Mediterranean Sea (fig. 51) for position of land-bridges, which is revealed by the soundings; also fig. 128.

produce of the east and west could be interchanged. Its northern shores, moreover, are deeply indented, and thus the countries on that side enjoy a maximum extent of coast-line and all the lands bordering it can contribute to its trade. No wonder then that the Mediterranean early became a populous centre, and although a greater seaboard development caused its importance to diminish for a time, it revived again through the fresh stimulus it obtained when a water communication with the Indian Ocean was effected.

The clustering of the people round the Mediterranean shores and on the islands did not take place all at one time, nor was it of quite such early origin as the concentration in river-valleys, as it presupposed man's having advanced a certain distance along the path of progress ; he must, in fact, have achieved the art of navigation.

The origin of the concentration may be traced to various causes. If we suppose that, at the close of the last Ice Age, a long-headed (Palaeolithic) type of man gradually wandered into Europe from the south and became thinly scattered in the more habitable parts, this population would tend to shift more and more northward as first steppes and then dense forest growth succeeded the reign of ice in central Europe. This vague drifting seems to have continued also in Neolithic times, when a similar type of man, i.e. still long-headed or dolichocephalic—but capable of producing better weapons—succeeded, emanating perhaps from the east, and when also, owing to favouring conditions, a certain amount of concentration on both Mediterranean and Baltic shores began. This new stage of culture is differentiated by the improvement in the weapons, which were frequently polished, and includes also the manufacture of pottery, some agriculture, and the domestication of animals. These last two industries led to momentous changes in the manner of life, resulting finally in the development of the community and specialization.

Towards the close of Neolithic times in Egypt, also near Susa and in Bosnia, some knowledge of the use of copper seems to have existed.

In the succeeding Bronze Age, but in some places rather earlier,

we have evidence that a different type of man—round-headed instead of long—migrated into Europe, possibly from the east, and advanced along the central ridges. According to some authorities, this people, called by them the Alpine race, drove a wedge between the existing peoples of the north and the south, causing the southerners to double back on the Mediterranean, while the northerners concentrated more particularly round the Baltic shores. Hence the race, originally one, became gradually differentiated into two widely divergent types,[1] that of the south being now known as Mediterranean Man and that of the north as Boreal[2] (or Nordic). Mediterranean Man, thus combining, in some degree, the racial capabilities of the ancient Egyptians with a far more favourable environment, led for a long period of time the van of human progress.[3]

It was while Egypt still flourished that the main current of the world's civilization began to sweep westward. This, the second phase of human culture, did not, however, occupy the whole Mediterranean area at once, but developed in successive stages in it, each stage being rounded off by a period of relapse into a lower stage of culture or into barbarism. Each set-back was due to the incursions of the wilder and more barbaric tribes from outside, who having outgrown the narrow confines of their homeland, where they had to snatch a scanty living for the most part from the mountain slope or from the great tangled forest

[1] Some writers consider that fairness is to some extent a result of environment, as it is found most frequently in higher altitudes or latitudes (see Ripley).

[2] The word 'Boreal' is introduced by Professor Myres and seems to me a much better word than 'Nordic'.

[3] In the new edition of Keane's *Man Past and Present* the orthodox view of man's origin is stated as being that one variable dolichocephalic race originated in southern Asia in Pliocene times, and that a section of this, passing directly into northern Europe, became gradually differentiated as the tall, fair, Boreal variety. Another section of this race, after migrating to North Africa, spread thence into Europe and founded the Mediterranean race on both sides of that sea. Finally, that in the western plateau region of Asia a brachycephalic type developed and subsequently spread westward right across the highlands of central Europe. Thus southern Asia is suggested as the cradle of the human race, the Mediterranean branch of it reaching Europe by way of Africa.

of the plain, turned greedy eyes to what seemed to them a land of promise indeed.

*First Mediterranean cycle. The Aegean.* Dealing first with these three ancient cycles of cultural development in the Mediterranean basin, the earliest was that of the Aegean area, in the eastern Mediterranean, and seems to have originated in the islands, spreading subsequently to the adjacent mainland. The excavations which led to these conclusions were first begun by Dr. Schliemann on the coast of Asia Minor, in the hope of being able to fix the site of Homer's Troy. His discoveries showed that the region had been populated long before the Homeric poems, and actually dated back to Neolithic times. Six successive strata of remains were found, all of which were finally proved to be older than Troy. Very careful investigations made by many people at different places, and extending over nearly forty years, gradually revealed the existence of a very ancient civilization,[1] which had prevailed throughout the Aegean Sea, and had its centre probably in Crete. This period of culture lasted from the Neolithic right through the Bronze Age, and in the later Bronze Age reached a very high stage of development, extending its influence to the mainland of Greece and throughout the southern Aegean. It also reached eastward as far as Syria and Palestine, westward to Spain and Marseilles, and had extensive intercourse with Egypt. This prehistoric stage of Mediterranean culture reached its zenith, as Sir Arthur Evans has clearly proved, in the Minoan age of Crete, which approximately coincides with the Bronze Age. The Early-Minoan period corresponds to Dynasties IV to VI of Egypt, the Late-Minoan period to Dynasty XVIII and later, i.e. about 1600–1200 B.C. At the close of this period, contemporary with the 'sixth city' at Troy, Minoan culture had spread to Cyprus and Sicily, had temporarily occupied Thessaly,

[1] The actual origin of this culture and of the people who initiated it is still under discussion. Some writers identify the people with the Pelasgians, but, as Professor Myres has pointed out, this term was used quite vaguely by Greek writers (*Journ. Hell. Studies*, xxvii (1907), p. 170). Sergi claims them as a branch of the great Mediterranean (Eurafrican) race, which entered Europe by means of the Mediterranean land-bridges, one of which connected Africa with Italy, through Sicily and Malta.

and reached the coast of Asia Minor. Between the Minoan Age and historic Greece we find a great gulf fixed, that has not so far been bridged and which marks a time of violent catastrophe during which the region was plunged in barbarism.

A fine description of the natural features of this region, given by Professor Myres,[1] shows how closely the developments in man's mode of life and thought were knit up with these features and seemed to be encouraged by them: Nature's generosity to man and the exquisite beauty of her form and colouring seeming to attune his feeling with hers. The discoveries at Mycenae, belonging to its highest period of culture, show that man possessed artistic power and inspiration hardly surpassed at the present day.

*Second Mediterranean cycle. Greek.* When the clouds of obscurity, which enveloped the close of the Mycenaean cycle, began to roll away, the main centre of culture is seen to have shifted slightly westward, from the islands to the mainland. The second Mediterranean cycle begins rather before the evolution of historic Greece, being reflected in the Homeric poems; it is clearly of a far more primitive type at first than its predecessor, even the art of writing having to a large extent disappeared. The complete eclipse of Mycenaean culture is generally ascribed to the incursions of barbaric tribes, who overcame the softer, more civilized Mycenaeans and, settling among them, gradually assumed some of their characteristics. These tribes did not arrive at one time, but the earliest, the Achaeans, to whom are traced the heroes of the Iliad, were traditionally already established in the country about 1250 B.C. Some believe that the new people swept in from the north,[2] perhaps from the Danube valley, but Keane[3] gives evidence in support of the theory that they were of Caucasic (i.e. north African) race and were previously distributed about the Iranian steppes, whence they gradually

[1] *Dawn of History.*

[2] Sir William Ridgeway identifies them with the iron-working man of the Hallstatt civilization.

[3] This theory, says Professor Myres, has not been accepted by any one working at Achaean things and has yet to run the gauntlet of the subsequent Hittite work.

peopled the peninsula of Asia Minor, and that they had already become differentiated into tribes before they entered Greece. The incoming peoples established themselves in cities, in which they formed the ruling caste, each city constituting itself as a separate state with individual customs and laws. Prosperity caused the populations of the city-states to increase very rapidly and great colonizing activity supervened. Each state founded its own colonies, which remained in close touch with the parent state and were modelled on it by the process of Hellenizing the non-Greek populations. Side by side with the Greeks, the Phoenicians, from their famous ports in the Levant, also extended their sway to both Mediterranean shores and to the islands, founding colonies, of which the best known was Carthage, established probably about 800 B.C.

The Greeks were not, however, wholly without rivals even in Europe, as by about 1900 B.C. the Etruscans had begun to establish their civilization in northern Italy, and in 500 B.C. their naval power was so great that, in alliance with the Carthaginians, they were able practically to exclude the Greeks from Tyrrhenian waters. Whence this culture was derived is a difficult question, but an alleged migration of Lydians[1] from Asia Minor to Italy in about the twelfth century B.C. seems to point to Greek origin, at any rate in part, the influence of Egyptian and Assyrian cultures being also clearly traceable. Etruria was richly adapted for agriculture, abounded in valuable forest-lands, and had access to mines; moreover, the goods conveyed by the ancient overland trade-routes for tin and amber, which terminated at the head of the Adriatic, largely found their way to Etruscan markets. It is, therefore, likely that these markets were much visited by traders, and this would account for the fact that, although the

[1] Herodotus mentions Lydians as landing at the mouth of the Po and crossing the Apennines into Etruria. A great wave of migration from Greece to Italy was taking place about 1000 B.C. Professor Myres, by inference, places the Lydian invasion somewhat earlier than this, as he describes 'a substantial body of sea-raiders, who struck out into the west about the same time as their namesakes, the Tursha, took part in attacks on Egypt'. The time he refers to was about 1230 or 1200 B.C. (see J. L. Myres, *Dawn of History*, pp. 206, 237).

cities became merged in the Roman state about 300 B.C., their wealth and prosperity long exceeded that of Rome itself.

The sixth century B.C. was one of great expansion in the Greek world, and, by the fifth, colonies fringed the whole Mediterranean coast and extended to Asia Minor and the Black Sea. The drawbacks due to political disunion in the parent country were to some extent neutralized by now one state and now another assuming the supremacy, but there was no complete fusion until the time of Alexander, who brought the whole area of the eastern Mediterranean under one rule, linking it up more closely with western Asia by pushing his frontiers to the very borders of India and, for a brief time, into India itself (fig. 136). In each of the cities that he established throughout his empire, Greek soldiers or traders formed the nucleus of the body politic, and thus, through Greece, the culture of the Mediterranean leavened the world.

The question whether, or how far, the peoples of the east, especially those of Bactria and India, really became Hellenized as a result of the conquests of Alexander is one that is difficult to answer. Some think that Greek civilization affected, at this stage, the whole current of life and thought in the east and was reflected even as far as Japan. Others consider that the Greek element preponderated only for a time and was soon merged in the native surroundings. It seems as if, in such little-explored regions as Bactria, excavations might reveal much, and the testimony of the spade is incontrovertible ; meanwhile what evidence we can produce in favour of Hellenization is meagre and unsatisfactory. It is obvious that Greek influence should be sought chiefly in the cities, and the proverbial expression 'the thousand cities of Bactria' appears to strengthen the argument on this side. Only four of these cities had any history, however, and the actual site of the famous Alexandria 'under the Caucasus' is a matter of debate. Further evidence is based on commerce, science—chiefly astronomy—and art. With regard to commerce, a long line of Greek-named Bactrian kings succeeded one another and had influence in the Tarim valley, through which pass the two ancient routes between east and west. We find, however, that the initiation of these routes is

FIG. 136. Map showing approximate extent of Alexander's Empire (335–324 B. C.) and the positions of five of the seventeen Alexandrias founded by him.

definitely claimed by the Chinese, as dating from about the close of the last Greek king's reign in Bactria. In considering water communication, we see that Alexander made a great effort to reach the Indus mouth and dispatched thence a large part of his army, and the fact that he apparently knew of this route rather argues its pre-existence. At the same time, extensive direct trading by western peoples between these ports and the west dates only from about 140 B.C., when they began to come within the Roman sphere of activity. The Greek influence traceable in the astronomy of India may also be of later date. The Buddhist art of north-west India shows undoubted western tendencies, and these can be recognized right across Asia eastward. Here again, we cannot prove that they were not transmitted later through the Roman Empire. That there was some direct Greek influence at an early date is borne out, however, by the numerous Bactrian coins of Greek design and apparent workmanship, also by the existence on the coins of Greek characters and the fact that they continued in use for two centuries after the last Greek dynasty had ended. Although these coins prove clearly the transmission of Greek artistic power, their superscriptions cannot be used as an argument that Greek speech was current at the time, any more than that our existing coinage shows Latin to be the language used in our streets and markets at the present day.[1]

*Third Mediterranean cycle. Rome.* As the power of Greece declined that of Rome developed, but whereas Greece had set her face mainly eastward in contemplating conquest, Rome turned also to the west, which fact had the result ultimately of bringing the entire Mediterranean basin within the zone of culture. In 266 B.C. Rome claimed the supremacy over all Italy; thus, in the course of about five centuries she had gradually, and as it were unconsciously, laid the foundation of a Mediterranean empire, which later expanded into a world-empire, finally comprising the greater part of the then-known world.

[1] For a detailed discussion of this important question see 'Notes on Hellenism in Bactria and India', W. W. Tarn, *Journ. Hell. Studies*, vol. xxii (1902), p. 268.

Following the example of Alexander, the Romans founded cities in the conquered territories and further proceeded to connect them up, in many parts, by means of an elaborate road-system, thus establishing land communications. Their rule was, however, like Alexander's, one of conquest by arms, and therefore left little permanent trace, in the subdued lands, of a culture forcibly imposed.

*Later phases of Mediterranean concentration.* The possession of such a prize as the Mediterranean coast-lands was never long undisputed, and the wilder peoples of the north, having gradually increased in numbers and strength, and feeling pent up within the confines of a far less favoured land, repeatedly burst through the mountain ramparts, leaving ruin and destruction in their wake. Thus the unity of the region was successively threatened by incursions of Goths, Vandals, and other tribes, and was finally broken up by its division into Eastern and Western Empires in 364 A. D. The decline of the Western Empire brought the third cycle of culture to a close, but Byzantium, the centre of the Eastern Empire, assumed for a time control of the sea, and eastern trade still flourished. The influence of the east was greatly extended by the Arabs, who in the eighth century A. D. swept, in a mighty tide of conquest, over all the southern shores and islands, including Sicily. They had even penetrated far into Spain and crossed the Pyrenees before Charles Martel, at the battle of Tours, A. D. 732, thrust them back into that unhappy peninsula, which, only after six or seven centuries of strife, was to succeed in driving the last Mohammedan invader out of western Europe. When the east began to be ravaged by the mighty struggle of the Crusades, Italy gradually took over the maritime traffic between east and west and established herself as a bridge between the two. Thus arose, in time, the Italian sea-towns Venice dominating trade in Greece and Syria, Genoa and Pisa in Asia Minor and the Black and Caspian Seas. As Italy became more and more the centre of the civilized world, trade-routes over the Alps were opened up, Milan and Turin receiving from other countries and exchanging with them goods by way of the Alpine passes.

Towards the close of the fifteenth century, as the age of exploration dawned, the ancient cultures of Greece and Rome were touched into new and ardent life by the 'Revival of Learning'. The mind of the western world, thrilled with the wonder of discovery, was awake and eager, and the escape to Italy of the Greek scholars from Constantinople supplied the necessary stimulus. 'Greece has crossed the Alps,' was the triumphant cry of one of the exiles, when the first rendering into German of Thucydides appeared and northern scholars, flooding into Italy, spread the seeds of culture broadcast over western and central Europe.

With the awakening of Europe the Mediterranean gradually lost its position as centre of the civilized world, for already the new phase of ocean-board development was beginning. All eyes now turned to the growing wonder of the west, and western ports grew rapidly, as the dwellers on the western seaboard began to recognize a new world. The Mediterranean was now a mere inlet, or outlet, of the larger ocean, its coasts yielding many useful raw products to the ocean shores. The opening of the Suez Canal, however, later restored the inland sea to some of its former glory as the world's great water-way, for by linking up the two great oceans of commerce, the Atlantic and the Indian, it now brings a far remoter east into touch with a greatly widened west.

So, all through the pages of history from its beginning, the Mediterranean has played its part and has formed an ideal home for man, where the fertility of the soil and clemency of the climate combine to make life easy, yet not so easy as to foster sloth and idleness; where, also, intercourse between different parts of the basin tends to advancement of knowledge, and where the contrast between eastern and western modes of thought promotes enlightenment. As stated above, the special type of man which developed in this region is known by anthropologists as of the Mediterranean race. He is believed to have entered Europe from North Africa, to have peopled both shores of the sea as early as Neolithic times, to have spread partly along the Atlantic coast westward, and into Egypt and Arabia eastward, becoming more and more prosperous as his spirit of adventure urged him more and more to a seafaring life.

*Inland sea-concentration. The Baltic.* While the Mediterranean area was developing with such wonderful rapidity and success, a similar movement was going on in Europe round the Baltic shores. This sea, extending not east and west, but north and south, is climatically far less favoured, but the proximity of the islands on the south-west to one another and to the mainland is an incentive to seafaring.

The peopling of the Baltic coast could not begin so early as that of southern Europe, as in Palaeolithic times an ice-sheet covered the region; we find, however, succeeding periods of culture, similar to those of the south but later in time. The Neolithic Age was greatly prolonged in this area and the introduction of metals took place at a far later date. This explains why the fashioning of stone implements reached a stage of perfection unknown elsewhere and bronze weapons appeared suddenly and in a highly finished state.

The first trace of a civilization in this region is the so-called Maglemosean,[1] the people being lake-dwellers on a sheet of water now silted up into a bog. The implements found are Palaeolithic in type, and it seems reasonable to suppose that we have here the last flicker of Palaeolithic life, driven northward or westward by the advance of the more sturdy Neolithic folk.

Following this development, but still early in the Neolithic period, towards the close of which time a dense and thriving population was more or less settled on the Baltic coast, we have evidence there of the existence of a semi-nomadic people, who lived by hunting and collecting shell-fish and left traces of their daily activities in the form of 'kitchen-middens', which served in turn as cooking places, dining-tables, and refuse-heaps for bones and shells, including occasionally the skeleton of an ancestor or so.[2]

The people of the later Stone Age differed widely from these. First of pastoral and later of agricultural type, they speedily developed a distinctive culture of their own which, although

[1] From Maglemose near Mullerup, a promontory north of Korsör on the west coast of Zealand (Sjælland).

[2] See the Danish National Museum at Copenhagen.

individual, evinces signs of contact with the south. The wide distribution of flint implements, in spite of the rarity of flint-bearing strata, shows considerable commercial activity; also the great diminution in quantity of amber towards the close of the period suggests that it became an important article of export. That, in spite of the comparatively adverse conditions of life, the people throve and multiplied, is proved by the great number of graves, of which there are three or four thousand on the island of Zealand alone.

The Neolithic Age was succeeded by the Bronze Age (about 2000 or 1750 B.C.), probably about 1,000 years later than the first use of bronze in southern Europe; some objects of beautiful workmanship belong to this period, notably the golden horse-drawn chariot of the Sun in the Copenhagen Museum.

The succeeding Iron Age (dated variously as A.D. 200–500) came in late in this region, but was greatly prolonged, and four periods can be distinguished: pre-Roman, Roman, post-Roman, and the Viking Age. In the Roman period there seems to have been fairly frequent intercourse with the south-east; probably the trade-route along the Vistula was already opened up. The post-Roman period is sometimes called 'the Age of Gold' because so many objects of workmanship in that metal have been found. The Viking Age which followed (A.D. 800–1000 or 1100) was the time when the peoples of the north, cramped by the confines of their somewhat ungenial lands, sallied forth in large numbers to win new homes by the power of the sword. In the preceding age they had already crossed the Baltic and spread along its eastern shores, but now, according to the sagas, they flooded over both as conquerors and as emigrants, and many a memorial stone in Sweden bears witness to the bravery of one who fell fighting on the further shore. They fared forth, not only eastward, but also towards the south and west,[1] and thus the Baltic, once a lake and now a sea, became a circle of influence, and the north, so long apart, from this time forth made its mark

[1] The settlement of Iceland was peaceful. In founding the new home in Iceland the Norseman immigrant flung the pillars of his hearth into the sea and established the home wherever they were washed up.

in Europe. Under the Valdemars (1157–1241) the Danish kingdom was the most far-flung domain in northern Europe and comprised the whole Baltic coast from the mouth of the Elbe to Lake Peipus. So threatening indeed was its menace to the peace of other nations that the Hanseatic League was called into being, as an effort on the part of the German Baltic ports in self-defence against it. The League, by establishing a busy trade with Venice and other Mediterranean ports, brought the basins of the two inland seas into direct relations with one another. The decline of the Baltic sphere of influence was hastened by the rise of Flanders in the fifteenth century, and when London under Elizabeth developed into the leading trade-centre of Europe, the reign of the Atlantic seaboard had already begun.

Before passing on to consider the later and wider spheres of culture, it will be well to try and correlate the happenings in the early centres so as to realize roughly the rate of progress in each.

The stages passed through in the four main early civilization centres are, very approximately, as shown in the table, pp. 338, 339.

*Other inland-sea civilizations.* The Mediterranean and the Baltic, although they were the seas destined to control the main stream of human progress, were not the only ones that saw the origin and growth of civilizations. The Gulf of Mexico, with its islands and the peninsula of Yucatan, early witnessed a remarkable cultural development. Recent American researches in Yucatan suggest the existence there about sixteen centuries ago of nearly 200 cities, some of considerable size, and this civilization in Guatemala covered an area of about 15,000 square miles. Also in Mexico and Yucatan traces of an ancient road have been found, which terminates abruptly at the sea-coast, but can be recognized again on the surface of the islands, showing their separation to have been later than the period of civilization.

The Mayas were pyramid-builders and, although still in the Stone Age, had developed a remarkably perfect calendar and a very complete system of hieroglyphic writing.

*Heliolithic culture.* It is pertinent here to note what has been recently observed, namely, that the latest Neolithic culture,

wherever it occurs, is marked by an extraordinary assemblage of ideas which, although they might arise sporadically at any time, are entirely disconnected and could not, therefore, have suggested one another. To take concrete instances: the use of huge stones as burial monuments is found in several regions, associated with the embalming of the dead, the tattooing of the chins of women, the circumcision of boys, the practice of couvade, the use of the swastika sign, and the introduction of weaving. These customs are more or less associated with Sun-worship; it seems reasonable, therefore, to assume that during this period there was intercommunication between the various culture-centres, and that the same race disseminated this special form of culture to many widely separated areas.[1] The map (fig. 137), taken from Elliot Smith's *Migrations of Early Culture*, shows the distribution of this, the Heliolithic phase of late Neolithic civilization, which originated probably in the eastern Mediterranean and Egypt about 4000 or 3000 B. C., just as that region was advancing into the Bronze Age. Thence it seems, in the course of some fifteen centuries, to have spread outwards until it was practically continuous along the shore-lines of the world, even crossing by island stepping-stones the broad Pacific Ocean. Later, the high tide of civilization, which produced this great culture-complex, seems to have ebbed, and it was only in certain favoured regions that a passing over into the next stages of culture occurred. In some areas, as in China, civilization became isolated and almost stagnant for ages, whereas in others, as in Mexico, it died out altogether.

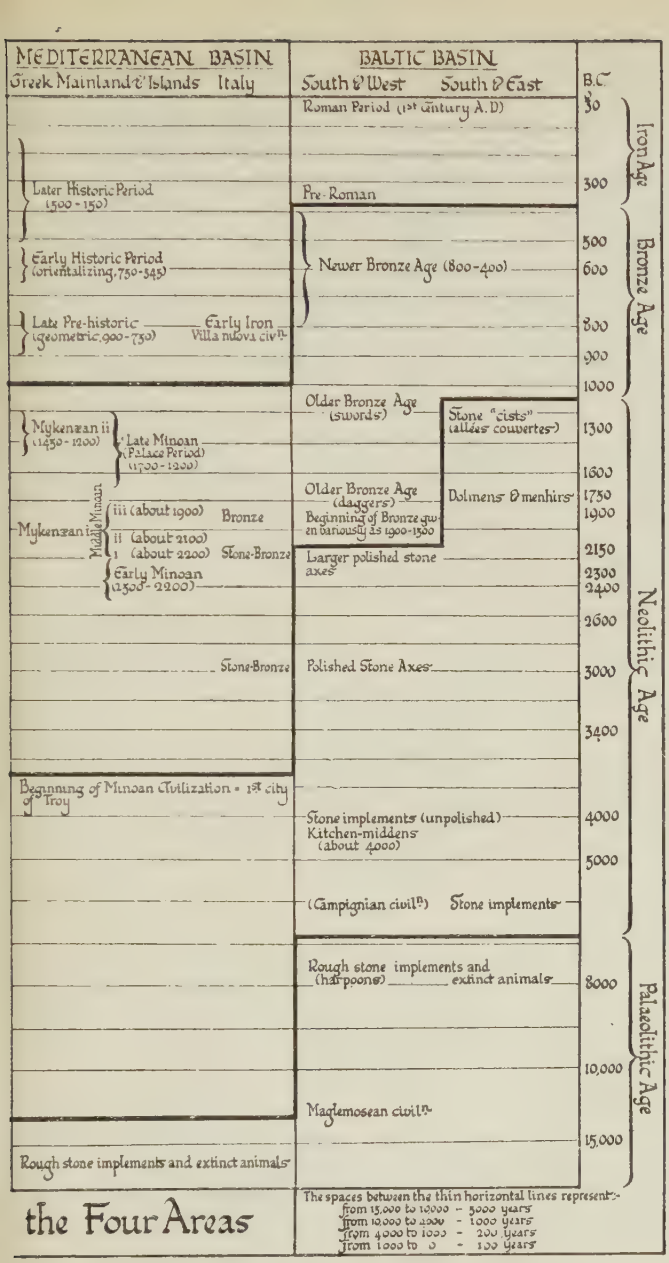
*Third phase of concentration. The Atlantic rim.* From the twelfth century onwards, although the inland-sea areas continued to flourish, we can detect a gradual shifting of populous centres towards the ocean shores. This brings us to the third phase of the concentration of peoples: that of the Atlantic rim. The

[1] A curious corroboration of this existence of intercourse between widely separated regions, in comparatively early times, occurred recently. A London paper reported that a learned Chinaman, arriving in Mexico City, had recognized, on an ancient monument there, a few symbols as being identical with some he had seen in his own country.

# Table synchronising

| B.C. | Ages | TIGRIS & EUPHRATES BASIN — Babylonia | TIGRIS & EUPHRATES BASIN — Assyria | NILE BASIN |
|---|---|---|---|---|
| 30 | Iron Age | | | Roman Period |
| 300 | | Macedonian Conquest (321) | | Ptolemaic Period (323)<br>Macedonian Conquest (332) |
| 500 | | Persian Conquest (Cyrus, 538) | | Persian Supremacy mainly from 538 (dyn. xxvii – xxx) |
| 600 | | Neo-Babylonian or Chaldæan Emp. (under Nabopolassar, followed by Nebuchadnezzar, 605) | | Chaldæan Conquest (605)<br>Dynasty xxvi (664)<br>Assyrian Invasion (670) |
| 800 | | | Second Assyrian Empire (Tiglath-Pileser III 745?) | Dynasty xxv (about 800) |
| 900 | | | | |
| 1000 | | | | Dynasty xxii (about 952 or 930) |
| 1300 | Bronze Age | Second Babylonian Emp. but Assyria often supreme (1035 – 731) | | Dynasty xxi (to about 1102 or 1190) |
| | | Akkad-Sumerian or Assyrian Empire (about 1970 under Tiglath-In-Arish & Shalmaneser I) | [1100] | New Kingdom: Dynasty xx (about 1200) |
| 1600 | | | | New Kingdom: Dynasty xix (about 1350) |
| 1730 | | Kossæan or Kassite dyn. | | New Kingdom: Dynasty xviii (about 1600) |
| 1900 | | | First Assyrian Empire (Tulilu – about 1900) | Dynasty xvi<br>Hyksos or Shepherd Period (ending<br>Dynasty xiii (abt. 1900 or 1800) [about 1700] |
| 2150 | | Later Sumerian Semitic: Hammurabi unites Sumer, Akkad and First Dynasty of Babylon. [Assyria | | Middle Kingdom |
| 2300 | | (Sumer-abu) | | |
| 2400 | | Later Sumerian Semitic: Dynasty of Isin<br>Dynasty of Ur | | Middle Kingdom: Dynasty xii (2400) |
| 2650 | | Sumerian: Dynasty of Akkad or Akkad-Sumerian Empire (under Shar-Gani-Sharri or Sargon I about 2650) | | |
| 3000 | | Sumerian: Dynasty of Kish | | Dynasties vi – xi (3000) |
| | | Early Sumerian Kings (Mesilim) | | |
| 3400 | | | | Old Kingdom: Dynasties iv-vi (Pyramid Period) about [3533] |
| 4000 | Neolithic Age | Excavations at Mussian and Susa show existence of Neolithic culture which probably extended to Babylonia | | Proto-dynastic Era: Dynasties i-iii beginning about 4500 or [3533] |
| 5000 | | Excavations at Nippur show existence of early city-community | | Pre-dynastic Period: Late – Ivory largely used.<br>Middle – Copper ornaments & objects<br>Early:– Flint knives and daggers |
| 8000 | | | | |
| 10000 | | | | |
| 15,000 | Palæolithic | Rough stone implements and extinct animals | | Rough stone implements and extinct animals |

NOTE
The chronological sequence is from below upwards


MEDITERRANEAN BASIN
Greek Mainland & Islands
Italy
BALTIC BASIN
South & West
South & East
B.C.
Roman Period (1st Century A.D)
Iron Age
Later Historic Period (500 - 150)
Pre-Roman
300
Early Historic Period (orientalizing 750-545)
Newer Bronze Age (800-400)
Bronze Age
500
600
Late Pre-historic (geometric 900 - 750)
Early Iron
Villa nuova civ.
800
900
1000
Older Bronze Age (swords)
Stone "cists" (allées couvertes)
Mykenæan ii (1450 - 1200)
Late Minoan (Palace Period) (1700 - 1200)
1300
1600
Older Bronze Age (daggers)
Dolmens & menhirs
1750
Middle Minoan
iii (about 1900)
Bronze
Beginning of Bronze given variously as 1900-1500
1900
Mykenæan i
ii (about 2100)
i (about 2200)
Stone-Bronze
Larger polished stone axes
2150
2300
Early Minoan (1500 - 2200)
2400
2600
Stone-Bronze
Polished Stone Axes
3000
Neolithic Age
3400
Beginning of Minoan Civilization • 1st city of Troy
Stone implements (unpolished)
Kitchen-middens (about 4000)
4000
5000
(Campignian civil.)
Stone implements
Rough stone implements and (harpoons)
extinct animals
8000
Palæolithic Age
10,000
Maglemosean civil.
15,000
Rough stone implements and extinct animals
The spaces between the thin horizontal lines represent:-
from 15,000 to 10000 - 5000 years
from 10,000 to 4000 - 1000 years
from 4000 to 1000 - 200 years
from 1000 to 0 - 100 years
the Four Areas

Atlantic Ocean, although possessing one great disadvantage, namely, that its opposite shores are not linked up by islands, so that it was long before its side furthest from Europe was even discovered, has yet an overwhelming advantage over other oceans, in that its trough nearly everywhere faces wide and gently sloping lands, traversed by large rivers. These broad plains being also in regions climatically favoured, not only the ocean rim, but the regions far behind it, became quickly subjected to the same influences. Thus the glory of Venice, Genoa, and Lübeck paled before that of Cadiz, Amsterdam, Bristol, Hamburg, and London. The development of the Atlantic shores falls entirely within the historic period, and, comprising as it does the whole history of civilization in western Europe and ultimately that of the other Atlantic lands, can be only lightly touched on here.

Before the dawn of history, Phoenician sailors had braved the perils of the straits and sallied forth beyond the Pillars of Hercules, as the existence of their famous port of Gades (Cadiz) testifies. The Greeks, whose activities on the whole extended more eastward than westward, were represented on the Atlantic by Pytheas, as early as 333 B.C., who sailed northward until the sea ' was like jelly '. These early voyages of discovery tell us nothing about the people of the Atlantic lands beyond the fact that Hanno, the Carthaginian (fig. 138), brought back from Africa tales of a hairy race whom, in deference to ourselves, we identify not as man but as gorilla. We find, however, that, from the Palaeolithic Period onwards, man had established himself in western Europe, in spite of conditions which were at first distinctly adverse. We can also tell by archaeological relics, that the opposite Atlantic shores, unknown in Europe, except to some few Scandinavian adventurers, were also peopled in pre-Columbian days by man in the Neolithic stage of culture.

The military conquests of Rome, especially during the first century B.C., extended her sway to the lands of the Atlantic seaboard, and by establishing these as separate dominions under one rule and also by opening up land communications, she prepared the way for empires and kingdoms yet to be. As

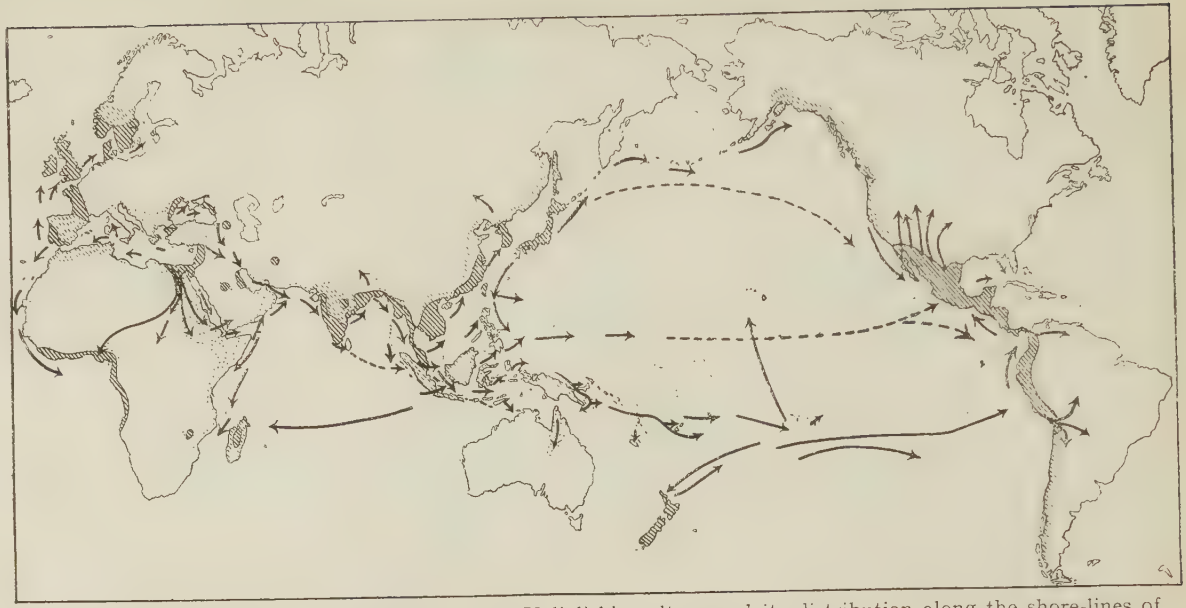


FIG. 137. Map showing origin in Egypt of the Heliolithic culture and its distribution along the shore-lines of the world. (The arrows indicate the possible direction in which it travelled. After Elliot Smith.)

Rome, even after the division of the Empire, still found she had clutched more than she could hold, she was obliged gradually to relinquish her grasp on the western lands. The weakening process, which had set in, was due largely to internal troubles, but was greatly increased by repeated incursions of barbaric tribes, Huns, Goths, and Vandals, who swept into Italy from the

Fig. 138. Voyage of Hanno.

north and threatened her very existence. Meanwhile a confederation of Germanic tribes, which had been forming in Central Europe, replaced the Roman power in Gaul and, spreading in course of time into Germany, founded the Frankish kingdom. This became in turn the parent of the Holy Roman Empire, founded with great pomp by Charlemagne, when he received his crown in A. D. 800 from the hands of the Pope at Rome. Another Germanic tribe, the Saxons, founded the Saxon kingdoms in Britain and so inaugurated the individual history of that island.

The actual beginnings of concentration on the Atlantic rim seem traceable to two distinct causes :

FIG. 139. Empire of Rome at death of Trajan, A.D. 117. (Boundary shown by shading.)
The black lines mark the directions of the principal Roman roads.

1. The great, general, oft-repeated flow of early peoples from the more populous east towards the unknown west.
2. The tendency of its own sparse population to circulate from one part to another.

In explanation of the first of these sources of movement, which may in part account for the migrations of the wild tribes that harassed Rome, it has been suggested that a slow process of desiccation was going on in central Asia, gradually converting what had been grass-land into desert and rendering the pastoral pursuits of the steppe-dwellers impossible. The Huns, advancing from the Volga, may have had their original home in central Asia; the Goths, domiciled according to some writers in the steppe region of Russia, may, for a similar reason, have penetrated north-westward and been dislodged thence by the advance of the Huns. The same general westward movement would carry the Vandals from the banks of the Vistula to Spain and so to northern Africa, from whence they plundered Rome. The desiccating process may have also promoted in Arabia that restlessness which, combined with the fiery and fanatic zeal which followed the establishment of the religion of Islam, drove the Arabs forth to 'conquer the world' by way of the Mediterranean's southern littoral, and thus profoundly affected the history of the Mediterranean coastlands, especially Spain. The result on the Atlantic rim of the westward migrations in Europe has been, generally speaking, to crowd back on it a larger proportion than is found elsewhere of the original inhabitants of the western lands. We thus find in Wales, Ireland, Scotland, Cornwall, Brittany, and the Basque Provinces, &c., a high percentage of inhabitants which approach the Neolithic type.

The tendency of the Atlantic peoples to circulate from one part of the seaboard to another may be attributed to various causes, the chief being that a hardy sea-coast race has a natural desire to adventure forth on the high seas, and that in this case there existed every incentive to seafaring. Thus, a broken and rocky coast-line makes internal communication difficult, as in Norway, or the barrenness of the soil makes an extended occupation necessary, as in New England; or, again, a consider-

able increase in numbers produces too great congestion in one part, as in Holland. Often the people are helped to decisive action by special causes, such as the presence of abundant timber for ship-building, as, again, in Norway; the quantities of fish available near at hand, as off Newfoundland; the spirit of curiosity and adventure, as in many cases, including England.

The result of maritime enterprise in the Atlantic shore-dwellers was to open up for them more habitable regions. At the dawn of the Viking Age, i.e. as early as the eighth century B.C., the hardy Norsemen swept the seas, settling in the more convenient creeks, estuaries, and islands along and around the coasts of England, Scotland, Ireland, Normandy, &c., even traversing the Mediterranean to Sicily and Constantinople. These Scandinavians colonized also on the coast of Greenland and, long before the days of Columbus, visited America.

All through the Early Middle Ages, in spite of the gradual development of the Atlantic region, a considerable part of the activities of Europe was still centred in the Mediterranean area. One crusade followed another in this region; here the Papacy had its home and from it ruled the civilized world; the great cities of its coast rose to power one after another, and countries like England, France, and Spain, which faced both ways, developed first on their eastern and southern coasts, the west sides remaining comparatively unimportant.

The special age of maritime enterprise, which began in the fifteenth century with the patient and systematic coasting explorations of the Portuguese, soon accelerated greatly the development of the Atlantic seaboard. These voyages, which originated with Prince Henry the Navigator, were continued long after his death, and resulted in a great struggle between the Portuguese and Spaniards for the ownership of the Spice Islands and for supremacy in the Indian Ocean. While these discoveries and colonizations were going on, an idea was gradually gathering strength that, the world being round, it should be possible and perhaps easier to reach the Indies by a westward route. Now, for the first time in the world's history, a new phase in the art of navigation was entered as, for a westward voyage, the ship must

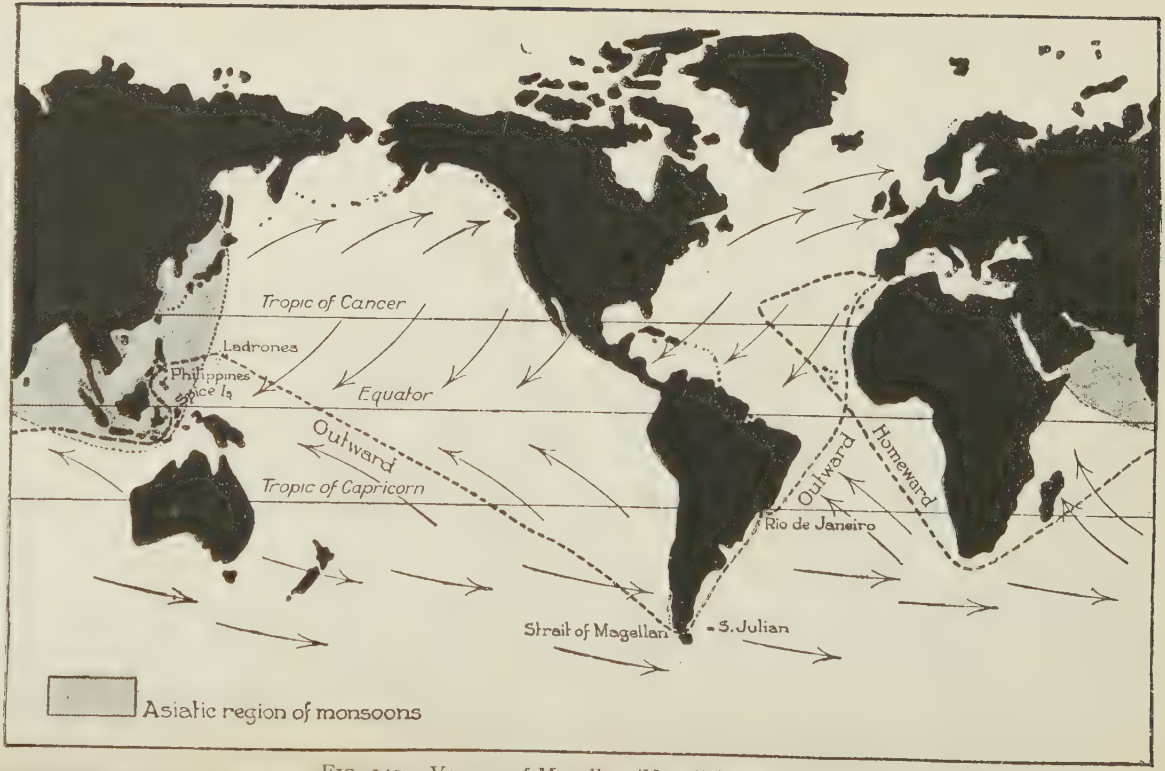



FIG. 140. Voyage of Magellan (Magelhães), 1521.

sail towards mid-ocean and the old safe coasting method must be entirely abandoned. Some few enterprising mariners were found to undertake the great adventure, and, of these, John Cabot was first to reach the mainland. The first expedition fully equipped for this purpose was, however, that of Columbus, who, after vainly offering his services to Portugal, finally sought the assistance of Spain and thus acquired for that power the first right of entry into the new world. The tragic voyage of Magelhäens (fig. 140), who lost his life in the Philippines in 1521, decided the fact of the New World's existence apart from Asia, and also proved that it was possible ultimately to reach the Spice Islands by that route. This latter discovery had an astounding but curiously differential effect upon the countries of Europe, for England, France, and the Low Countries now found themselves in the van of the world's progress, while the Mediterranean lands sank into the background; and the recently developed trade-routes of central Europe, on which the welfare of Germany so largely depended, suffered with them. As, after the opening up of the ocean's further shore, the Atlantic rim developed, the shifting of the centre of world-growth began really to take effect. The rising naval power of the Dutch enabled them gradually to supersede the Portuguese in several of their colonies, and the French, sailing up the St. Lawrence, established their rule in Acadie. England, hitherto on the outskirts of the civilized world, from this time became the jumping-off ground for many of the activities faring westward, and thus in course of time absorbed the carrying trade of nations. Becoming more and more cramped for space within her borders, she founded colony after colony on the further side, and as all these increased in size and importance, so also their commercial relations with the European shore developed. An immense further impetus was given to this trade by the severance of the colonies from their parent state and their union in 1776 into one republic.

Since then the cultivation of cotton in the United States, begun in 1786, followed by the scientific discoveries of the nineteenth century, especially those involving the uses of steam, coal-gas, and electricity, have stimulated this trade to a marvellous

degree. The whole coastal plain of North America was soon teeming with eager life, which not only called into equally sudden prominence a number of European ports facing that way, but also sent out feelers into its own hinterlands, until it gradually drew the whole breadth of the continent into a share of its activities. The so-called mushroom growth of American cities has often been commented on, but equally rapid increase has taken place in some instances on the nearer side. Thus Hamburg and Liverpool added 70,000 to their population in ten years, Glasgow and Cardiff in less than thirty years were transformed from small town and village to vast cities. England's change of front from east to west was also paralleled in France, where Le Havre and Rouen increased as the Mediterranean ports declined. Germany, unfortunately for herself, consisted then of separate states, and so had not the power to command a wider seaboard; this difficulty was, however, largely met by the making of ship-canals and the extensive utilization of Dutch ports.

*Fourth phase. Pacific rim concentration.* Historians tell us that the Atlantic phase of world-history, which began about the time of Julius Caesar and has continued until now, is gradually giving way to another, in which the world of the future may have no longer an Atlantic, but a Pacific outlook.

This latest phase, about to open when the war suddenly gathered all new activities and developments into its own net, had already made itself felt in the peopling of Australia and New Zealand, the adoption of western modes of thought in Japan, the opening up of China and the coupling of east with west by means of the great New World trans-continental railways. The outbreak of war, however, distracted all attention from what should have been the inauguration of the fourth great phase of human development, so much so that the opening of the Panama Canal in 1915—that crowning achievement, which converted into actuality some centuries of dreams—passed comparatively unnoticed.

Those tragic years, 1914–19, which saw more destruction than perhaps the next quarter-century can quite make good, have

brought us to a stage in the world's history, when the exhausted nations turn with relief from the war-riven land-hemisphere of the globe to that water-hemisphere on the other side, the smooth surface of which has remained comparatively unruffled by the breath of conflict. The Pacific Ocean, then, has justified its name, and its peaceful waters, extending across half the globe, caress the shores of countless islands in that most favoured part of the world, where the rays of a tropical sun vie with the moisture-laden breezes from the sea to woo the good graces of Nature in her most lavish mood. A girdle of land encircles the ocean on the north in an almost continuous half-ring, but gapes widely towards the south, and, across the vast expanse, the old nations are turning to one another new faces lit by hope.

The problem, which had begun to occupy men's minds in 1914, has, in a measure, changed its aspect through the war, but it is none the less vital on that account, and it behoves us all to try and obtain a clear view with regard to the policy of Pacific development. The great question in the minds of those concerned still is what kind of history will be written on this fair and so far almost unsullied surface. The unrecorded history of the ocean extends back into a past almost as remote as that of its antipodes, but we only know that some of its archipelagos and islands saw the development of that Heliolithic culture which seems in late Neolithic times to have encircled the world. The present Polynesians, a brown race of Caucasic origin, probably derive thence their love of ships and seafaring, which is so marked a feature in Fiji that the carpenter ranks almost equal with the chief. We believe, however, that the introducers of Heliolithic culture, who left lasting memorials of themselves in the megaliths of Easter Island and elsewhere, displaced a dark race of the wilder Papuan type. This is still represented in certain areas by the Melanesian peoples, the Micronesians being a mixed race of probably later origin. When Magelhães first ventured into the unknown waters of 'el mar pacifico', he steered north-west, thus missing nearly all the islands; but the later explorers, first the Portuguese, then Spaniards, Dutch, British and French, gradually discovered, lost, and re-discovered one island-group

after another. In their wake came the traders, many of them, unfortunately, of doubtful honesty, and although in some parts the influence—moral and political as well as religious—, which had been acquired by missionaries, helped to counteract evil practices, yet the kidnapping of natives for Australian and American labour markets became a danger, which threatened especially Australia and New Zealand. At last, Great Britain, to protect her colonies, passed a law regulating this traffic, and in 1874, two years later, annexed Fiji, where a London Missionary Society station was already established. Subsequently, a British High Commissioner was appointed to guard British interests in the Western Pacific.

Meanwhile other nations were establishing each a sphere of influence, so that, at the outbreak of war in 1914, American interests were centred mainly in the north, from the Philippines to Hawaii. The German sphere embraced a more central region east of the Philippines and north of New Guinea, including part of the latter island, known as Kaiser Wilhelm's Land.[1] British influence was established among the islands extending from Australia north-eastward to America Island and eastward to Cook Islands, while the French centred chiefly in Marquesas and the neighbouring groups. Abutting on the British sphere were the French possessions of New Caledonia and the New Hebrides under joint control with Britain, while the Samoan group, and the small islands west of it, were divided between the United States, Germany, and France respectively.

In the light of recent events, our perceptions, quickened by the war, reveal to us the danger then threatening the Pacific in common with other areas.

The great idea of *Weltpolitik*, hatched originally in the fertile brain of Bismarck, involved the establishment of an African, an Oceanic, and an American Germany. This policy necessitated the annexation of certain islands in the Pacific, which was actually being carried into effect when the Franco-Prussian war exhausted

[1] At present the former German possessions, consisting of the Caroline, Pelew, Marianne Islands —with the exception of Guam—and the Marshall Islands, have been placed under the jurisdiction of Japan.

for a time Germany's resources. Gradually, however, part of New Guinea and the Bismarck archipelago were secured, and later, chiefly by private purchase, a portion of the Samoan group. That this occupation of strategic positions was not wholly accidental is suggested by the fact of the following events occurring more or less simultaneously :

1. The penetration into China of numbers of German traders and missionaries.
2. The seizure of Kiau-chou and the Shantung peninsula.
3. The Germanizing of the military and educational systems of Japan.
4. The increase in number and size of the ships of the German navy.
5. The establishment of the mild quasi-British rule of Dr. Solf in Samoa.

We thus see that the Pacific had reached, in 1914, a most critical stage in its history and stood at the parting of ways, which would have finally opened out and established themselves when the Panama Canal spread wide the gates of the Atlantic.

The question now of great moment to all the nations interested in the Pacific area is, not which shall own this island or that and so be enabled to snatch the most profit from newly opening fields of enterprise, but which of the two theories of government shall prevail :

The first, that of a power in pursuit of new colonial possessions, to be added like beads to an existing string and to be exploited for the benefit of the home country more or less regardless of the welfare of the inhabitants.

The second, reckoning new colonies as a trust, in which each one requires separate treatment and consideration, so that it may develop along lines of its own individuality for its own ultimate advantage.

The decision of this great question rests with the powers which have met upon the Pacific shores : Great Britain, the United States, Japan, and, perhaps still, Germany. The two former have shown themselves to be imbued with similar theories as regards development and can be expected to uphold an

enlightened and, if necessary, an altruistic policy. Japan, to some extent a convert before the war to the apparent perfection of German military methods and *Kultur*, may now decide to free herself from outside influences and to follow rather the dictates of her own initiative; Germany is at the moment in abeyance, trying to peer into a future as yet unknown, both as regards policy and power. For America the decision is momentous, as her Pacific seaboard is far from having attained its full development and the waters of the ocean bring her into touch with the teeming millions and ancient civilizations of Asia. For Great Britain herself the question is also one of the first importance, as the wide, comparatively empty lands of Australasia on one side of the ocean, and of Canada on the other, look to her for guidance into what should be paths of great development, leading to a fair and prosperous future. The expansion possible to these great dominions, combined with the opening up of new trade and trade-routes among the islands, whose potential wealth is based on the beneficence of the tropical sun, might go far to help in healing the hideous wounds inflicted by war.

Thus, on a note of interrogation, we must conclude our description of history's phases, observing, however, that in all four, geography has played a leading part. In each, moreover, movement, even if unconscious, has been in the direction of shore development, but on an ever-increasing scale: (1) the river shores; (2) the inland-sea shores; (3) the shores of the lesser; and (4) the shores of the larger ocean—thus the history of geography is the history of the evolution of shore-lines.

## XXIX. Natural Laws determining the Positions of Cities and Boundaries

As the concentration of population tended to take place in any area, so the struggle for existence became keener, new faculties were called out, and a gradual differentiation of occupations took place. We believe that, even in prehistoric times, man's work was usually distinct from woman's, but when, later

on, a sedentary life became the rule, many needs arose which are incompatible with a wandering life in which man and woman had to shoulder all their possessions. The most obvious of these in temperate climates was a permanent dwelling; in tropical lands, even at the present day, it may be dispensed with, for temporary erections provide sufficient shelter from rain and sun. In some parts of Central Europe and in the British Isles, caves at first served this purpose, but one imagines that, even so, man would suffer terribly from cold at times, especially as the great ice-sheet had not long receded thence; moreover, he would be called upon occasionally to share his refuge with, or abandon it to, the hyena and cave-bear. Of this life we know little beyond the fact that, in spite of the perils of existence, man early developed the artistic instinct[1] and the power of fashioning implements for his use.[2]

In a region of lakes his life was less perilous, for log dwellings were built on piles on the surface of the lake, near its margin, so that their owners could venture on shore in the daytime and graze their cattle on the shores of the lake, but at night they retired into the huts and removed the bridges communicating with the shore. Traces of such dwellings have been found near Glastonbury and also on some of the Swiss lakes. Similarly, at the present day, whole villages are seen on the Canton river; here the huts are built on boats in the centre of the stream, and a large floating population has subsisted thus for generations.

*Distribution of population. Tendency of population to form clusters.* As with primitive dwellings, so with later ones of a more permanent type, they might be isolated from one another or clustered together in large or small communities. We seldom, however, find the population evenly distributed over the whole area, and when this is the case there is generally a definite reason for it. In Brittany, for instance, the hard impervious rock forms natural reservoirs for water, dotted irregularly all about the surface; consequently the population is scattered broadcast. In

[1] See reproduction of Palaeolithic drawings, Wells's *Outline of History*, Part II, pp. 33, 60, 61.

[2] See pins, needles, &c., in Torquay Museum.

Yorkshire, also, before the use of machinery collected the population into definite centres, it was distributed in widely distant farms; in parts of Wales, where sheep-farming is the main occupation, the same feature is observable. More commonly the population is bunched on streams and rivers, originally because of the need of water, as it still is in the department of the Marne, where the rain is rapidly absorbed by the porous soil. Even if abundance of water is obtainable in various parts of the region, as it is in the gravelly patches round London, still the main populous centre is along the watery highway. Thus need of water, variety in soils, and very many causes affect the distribution of the population, and, on the whole, we find—other things being equal—that the gregarious instinct prevails and farms clustering together form hamlets, hamlets develop into villages, villages into towns and so on. The danger of the present day, in England at any rate, is that the whole population tends to centralize itself in towns, most of all into few large cities, finding there new labour, and abandoning the more healthful and most useful toil of the country-side.

*Origin of cities.* The next point to consider, then, is the origin of cities and the causes that have contributed to their development on such a gigantic scale as is seen at the present time.

*Sites fixed by natural geographical laws.* The most important fact to grasp in connexion with cities, small or great, is that their site is not an accident, but is due to the working of fundamental geographical laws. A few modern cities, such as Berlin and Petrograd, are well known to have arisen as a direct outcome of design on the part of man; but most cities, and all ancient ones, have a perfectly well-established *raison d'être*, if we can only trace it. It is usually safe to assume that a city owes its exact position to the fact that it possesses a natural means of supplying some definite human want: thus Palmyra—the ancient Tadmor—was situated in an oasis on the main trade-route between the Syrian ports and the Persian Gulf, the valuable deposits of salt in its vicinity forming an important contribution to that trade. By tracing the origin of such cities we can clearly prove that political geography has no separate existence, nor is it arbitrary,

but merely the natural outcome of man's development on lines originally laid down by the physical conditions.

The most urgent human needs determining the choice of a site are :

1. Need of water for drinking, &c. : a city is placed, therefore, on a river or near springs or both. London is on a river, and

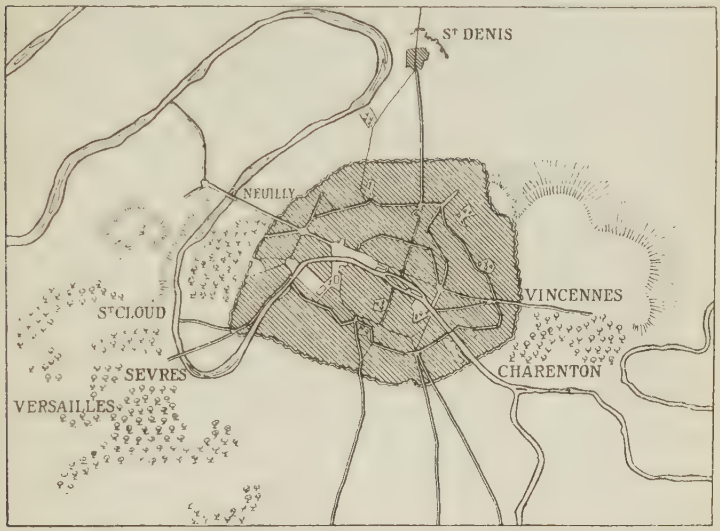



FIG. 141. Paris, situated partly within and partly astride a meander of the Seine.

many places close to it, but originally separate from it, are built on gravel patches on the clay, where the water, absorbed by the gravel, flows out in the form of springs : e.g. Wimbledon, Blackheath, &c. ; a city with both river and springs is Bath.

2. Accessibility. Access by water was often the easiest and quickest in ancient times, so most cities are built near rivers on that account, the river serving as means of communication before the construction of roads. As late as the eighteenth century we read in *Sir Roger de Coverley* that the watermen of the Thames plied a ready oar.

Even the particular portion of the river chosen has a special significance ; it may be :

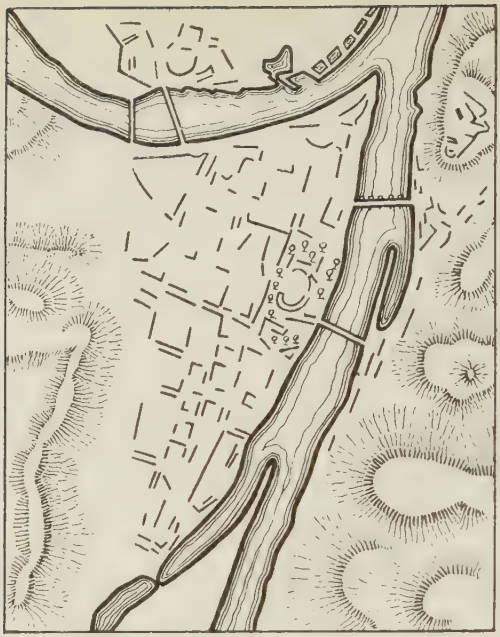


FIG. 142. Koblenz, situated at confluence of Moselle and Rhine. The fortress of Ehrenbreitstein is also indicated in the north-east corner.

FIG. 143. Stirling, partly surrounded by the River Forth.

(*a*) On a meander: e.g. Paris, which lies in a loop of the Seine (fig. 141), but see also under (iii), p. 358.

(*b*) Near a ford: e.g. Westminster. The main road to the north crossed the Thames by a ford at this point.

(*c*) At a confluence of two rivers: e.g. Oxford, Koblenz (fig. 142), Mainz, Belgrade, Khartum, and many others. The

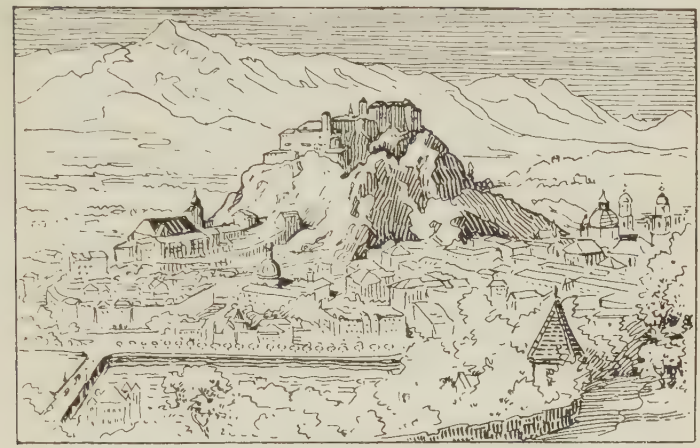


Fig. 144. Salzburg, the ancient Juvavum, with fortress of Hohen-Salzburg.

accessibility is greatly increased at the junction of rivers, because this facilitates the construction of a three-way road.

(*d*) At the first possible bridging-point counting from the mouth: e.g. Buda Pest, Newcastle-on-Tyne.

(*f*) On an estuary: Southampton. This city is in the unique position of having double tides, because the tide up the Solen and that from Spithead do not coincide.

Other estuary towns are: Lisbon, Le Havre, Antwerp, all owing their importance to the excellence of their harbours.

3. Ease of defence. Natural protection to a city is afforded in the following ways:

(i) When one side or more is protected by a river: e.g. Stirling (fig. 143), Sion, &c.

(ii) When there is an eminence near which makes a good

lookout-place or citadel whence the approaching enemy can be seen: e. g. Athens, Rome, Salzburg (fig. 144), Lincoln, Quebec, and many others.

(iii) When the town is more or less isolated by water: e. g.

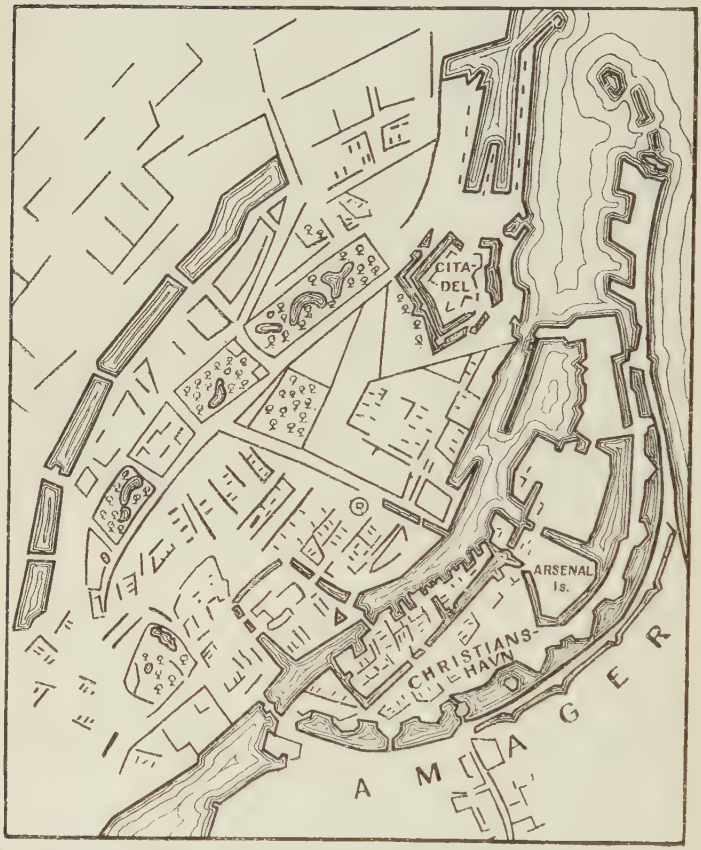



FIG. 145. Copenhagen, situated astride the Kalvebod Strand, which separates the Island of Zealand (Sjælland) from Amager Island on the south-east. The city was founded in the twelfth century and strongly fortified in the sixteenth.

Constantinople, Venice, Gibraltar, Valetta, New York, Copenhagen (fig. 145), &c. In Paris just the centre of the city is on islands (fig. 141).

Chester (fig. 146) combines several of these advantages. Partly isolated by the River Dee, which lapped against its western walls in Roman times, it stands some thirty feet above the broad plain, which reaches on the west almost as far as to the Clwydian hills. The Romans, for further security, usually surrounded their cities by a wall. The Chester walls, otherwise complete, have now

Fig. 146. Chester, showing the encircling walls, the river-plain (Roodee) on the right, and the hills beyond. (From a drawing in the possession of Messrs. Phillipson & Golder of Chester, with their kind permission.)

been pierced by the railway at the north-west corner. The ancient walled town of Rothenburg, in Bavaria, which stands high above the Tauber ravine, still has its fortified gateway (fig. 147).

(iv) Where the city is walled in by mountains on one or more sides and has to be approached by narrow passes: e.g. Turin, Milan, Innsbruck, Kabul.

4. Where a particularly favourable platform exists owing to the proximity of a river or sea and presence of fertile soil, as on river deltas: e.g. Alexandria, New Orleans; or lake deltas: e.g. Interlaken, Zell-am-See (see above, fig. 69).

5. Where several routes converge, rendering the position an important and central one: e.g. Vienna, approached from four different directions through gates or passes.

Vienna furnishes a good example of a city the site of which is in many ways ideal; its position is therefore analysed more fully as follows:

Vienna (fig. 148) may be compared to a key fitting into the central lock of Europe, for a turn of this key opens up access to either of the four boundary seas. The lock is outlined by the converging massifs of the Alps, Moravian Heights, and Sudetes on the one side, and the Carpathians on the other. The almost continuous highlands of the west are breached by the Danube Valley and again subdivided by the valleys of its tributaries, so that convergent on Vienna are the various ways which connect the Baltic and North Sea plains with the coasts of the Black Sea and Adriatic.

In the very earliest times the routes across Europe converged on Carnuntum (Pressburg or Bratislava), situated where the March joins the Danube from the north; but the development of the west seems to have shifted the traffic centre slightly upstream, so that in Roman times Vienna (Vindobona) was already rising in importance. Vienna is approached by four natural gates or passes:

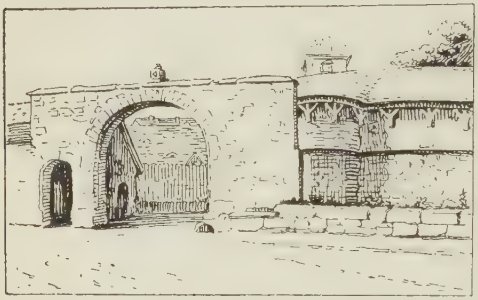


FIG. 147. Spitaltor of Rothenburg, with circular bastion and portion of city wall. (From a photograph by M. F. Skeat.)

1. Through the Austrian Gate, the Danube Valley places it in direct connexion with the Alpine region and its inexhaustible supply of timber, the salt region of the Salzkammergut, the rich plateaux of Bavaria and Franconia, and finally, by approaching the Rhine Valley, opens up access to the west of Europe and the North Sea coast.

2. Through the Moravian Gate, by means of the March Valley, Vienna is brought into contact with the valley of the Oder, central Germany, and the Baltic coast; this route passes through Bohemia and traverses the wealthy mineral districts of Silesia and Saxony.

3. Through the Carpathian Gate, the lower Danube brings Vienna into connexion with the fertile Hungarian plains and ultimately the Black Sea coast (the Hungarian name for Vienna is Bécs).

4. The Semmering Pass leads from Vienna to Styria, Karinthia, and the Adriatic coast, so connecting it with the eastern Mediterranean basin.

In these ways we notice that Vienna fulfils the following ideal conditions as regards site:

(*a*) It is near a river;

(*b*) It is near more than one confluence;

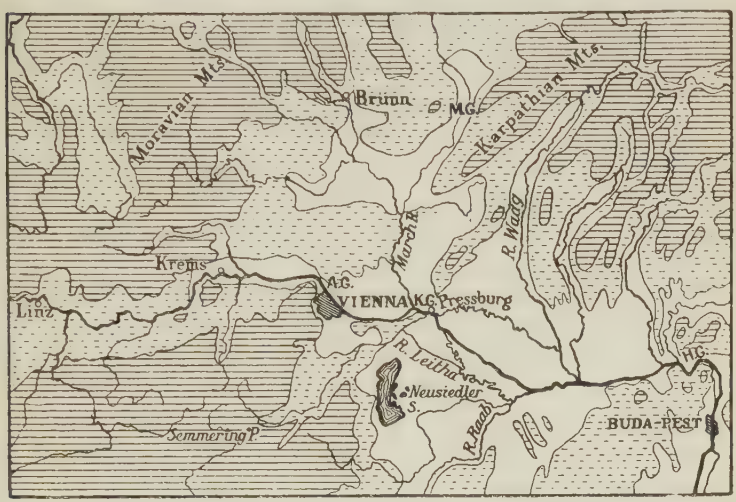
(*c*) It is protected on one side by mountains and on the other by a river;

(*d*) It is at the point where the river forsakes the mountains and enters the plain, so that, in the old days, one means of transport would be exchanged for another;

(*e*) It has access to several very diverse regions, with abundance of natural produce;

(*f*) It is at a natural meeting-place of highways.

6. At the point where one mode of transport changes into another thus: (*a*) land transport may be exchanged for water transport or the other way round. Port Arthur and Duluth on




Scale: 1 inch = 64 miles. Contours at 1,000 and 2,000 feet shown by shading.

FIG. 148. Map showing position of Vienna and the chief passes by which it is approached. A.G., the Austrian Gate; K.G., the Carpathian Gate; H.G., the Hungarian Gate; M.G., the Moravian Gate.

Lake Superior are placed where the grain is transferred to ships; Liverpool, where the cotton is transferred from ships to rail and distributed to the cotton towns of South Lancashire; New York, where agricultural and other produce is loaded on to vessels.

(*b*) Where merchandise brought across a desert is collected for regular road, river, or sea transport: e.g. Damascus, Timbuctu.

(*c*) Where the goods brought over mountain passes are collected for distribution: e. g. Tiflis, Turin.

7. A few towns have arisen by purely artificial means. Some of these are traceable to the whim of a monarch; thus Petrograd was established on a partly artificially-prepared surface, owing

to the wish of Peter the Great for a port in that position ; Antwerp superseded Ghent and Bruges, because Maximilian, in the sixteenth century, blocked the canal between Bruges and the sea. A few, such as Blackpool, may owe even their site to the holiday-making spirit of the industrial population, which seeks an outlet on the coast, and has been known to fling away the savings of a year in one glorious fortnight.

8. Where abundance of some particular commodity exists and is readily obtained. This was the case with clay in ancient times, when its use for water-vessels was realized, and this may have greatly contributed to the importance of London. The presence of abundance of flints for weapons, &c., probably initiated the development of towns in south-east England. Ely, the Fenland city of refuge, owes its position to the elevation,[1] but its name to its abundant supply of eels.

*Importance of minerals in determining sites.* In this connexion it is important to realize that certain minerals have played a very important part in fixing the sites of towns, and this increasingly so in modern times. Even in early days, as mentioned above, it was soon proved that minerals were more effective as vessels for carrying water than either hollowed-out fruits or branches of trees, although calabash cups are still seen in the West Indies, and a long hollow bamboo is the water carrier's utensil in the Malay States. Baked clay was early used for this purpose in desert regions, where the Sun served as baker, and also, in other parts, for building material. Stone for implements was greatly needed until the use of bronze or iron was known, and even in prehistoric times ornaments played their part, hence the traffic in amber. The first useful metals to be discovered were copper and tin, iron being originally employed only as an ornament. Gradually the instinct for barter led people to take minerals in exchange for other goods, and resulted finally in the establishing of an artificial value for copper, bronze, silver, gold, and to some extent nickel,

[1] The fact that Ely is on a height seems to have impressed itself on the imagination of those who do not know the Fenland. In the series of wall-paintings representing Danish history, in the castle of Frederiksborg, Ely appears as situated on a *beetling crag!*

purely for purposes of exchange. An abundance of mineral products, or the need of them, seems to have had the effect more than anything else of promoting intercourse between different communities. A people, for instance, which possessed material suitable for its weapons and implements might have practically no external needs, but was bound to be visited either peacefully or otherwise by those who lacked this commodity and were obliged to go in search of it. Thus the rich deposits of copper ore possessed by Cyprus probably caused that island to become one of the centres of Aegean civilization, and in Roman times the best copper ore was still obtained there. The Cassiterides or Tin Islands were early visited by the Carthaginians in search of tin. These two metals, copper and tin in combination, produced the alloy called bronze, which was, during the Bronze Age, in universal use for weapons. Salt, again, played an important part as an object of exchange and reacted favourably on trade; cakes of salt were even used as money in Abyssinia and Tibet. Of the metals used for coin, gold has had a remarkable effect in inducing colonization. Several towns in Australia sprang into existence entirely owing to its discovery in their neighbourhood; others arose similarly in California, the Transvaal, and, later, Port Dawson and other places in the Klondyke district. The minerals, however, that have influenced the existence of towns in the most marked degree are coal and iron. As the discovery of the uses of steam and coal-gas led to the invention of all sorts of machinery, these two minerals, when found together, assumed an ever-increasing importance, hence the complete transformation of that part of England now called the Black Country, not so long ago a fertile and very beautiful agricultural district. Now large cities are dotted over every important coalfield in Europe and America, and in very active centres, such as south Staffordshire, south Lancashire, and the Ruhr basin, the towns have spread to such a degree that the whole district seems welded into one vast city, outrivalling even London in populousness.

*Natural geographical laws operating towards decline of cities.* The decline of cities, or the transference of their population to other areas, can also be traced to definite geographical causes thus:

1. The silting up of harbours has tended to destroy even the most flourishing intercourse by water: Adria, which once gave its name to the Adriatic, is now some miles inland, and has no importance.

Rome is no longer available as a port.

The old Cinque Ports have suffered in this way to a remarkable degree, although their loss of prestige is not wholly owing to this cause, but to the diversion of the main stream of traffic. Dover, however, the only one of the original ports from which the main traffic was not diverted, has had this danger removed by the construction of a large artificial harbour, consisting of more than two miles of concrete breakwater, enclosing a harbour nearly one mile square.

2. The increase in the size of ships will no longer admit of their approach in many cases. Thus Bristol as a port has yielded to Liverpool; Manchester, on the other hand, attained practically the position of a port through the opening of the Ship Canal.

3. A change in the kind of power used for manufactures has destroyed some trades, as, for instance, the woollen trade of Suffolk and the eastern counties, once so important that Lindsey,[1] Kersey, Worstead still linger as the names of the places that produced the materials so called; also the size and beauty of the churches testify to the existence of former important centres of population. The industry died out owing to the substitution of steam power for human power. The wool trade, which once flourished in the Yorkshire dales, has forsaken them for the towns, here also owing to the change from human or water power to steam power. The iron once smelted by charcoal from the trees of the Weald is no longer worked in Sussex and Kent, the iron industry being now almost entirely relegated to the coalfields. For this purpose the Kent coalfield is not yet sufficiently developed.

It will be noticed that these last changes are not due to direct disqualification of the site, but were bound to follow in the wake of advancing civilization.

[1] Lindsey (formerly Lynsey) probably owed its name to the material called 'linsey-woolsey'.

*Natural geographical laws determining boundaries.* In early times the different settlements of mankind were not necessarily defined by any boundaries. The forest-dwellers, for instance, would not scatter themselves over the whole forest region, but would only penetrate into those parts which best supplied their immediate needs, and the steppe-dwellers would limit their wanderings for the same reasons. It was only in later times, when civilized man began to utilize each portion of the land's surface, and when his increasing numbers, due to prosperity, caused him to impinge upon his borders, that boundaries began to have significance. Even then, unless there were a quite definite natural boundary, such as a river or mountains, it was customary to have a debatable land of varying width between the communities, this being not exactly owned by either. Thus it was that when the early American settlers purchased land from the original inhabitants, two tribes might both lay claim to a certain strip of land, which had to be paid for twice over. Another curious instance of neutral ground of this kind was seen along the mountain strip separating the Swedish and Norwegian sides of the Scandinavian peninsula. This strip, not being owned by either people, and indeed being hardly suited for their occupation, was gradually invaded by a tribe of Finns, who drove in a kind of wedge between the eastern and western peoples. Sometimes a piece of neutral ground of this kind is an important safeguard, as, for instance, the strip dividing British Gibraltar from the territory of Spain; the same principle underlies the establishment of the chain of buffer-states in eastern Europe.

Geographical boundaries became fixed, or remain fluctuating, according to their nature. If reinforced by some more or less unnegotiable geographical feature, such as mountain or ocean, they usually remain stationary, and in many cases help greatly in the consolidation of the races they enclose, by promoting unification and a national feeling. Such is the case of the British Isles, Spain, and Italy. In the former the sea alone suffices to define the boundaries; in the two others, an even more effective barrier is their lofty mountain wall. Often a river forms a useful bounding line, as the broad Danube flowing between Bulgaria

and Rumania; or a chain of lakes may serve, as between Canada and the United States. Or again, a desert is a good boundary for an agricultural people; hence the differentiation between China's original confines and Mongolia, also the westward definition of Egypt. Of these different kinds of natural boundaries, the sea or ocean was, in the remote past, the most potent. Examples of this are the extraordinary difference between Africa when first explored and Europe at that date; similarly between Australia and India or China.

Next to the sea, the desert is the most marked divisional factor, and of deserts mountains are only a specialized form. The population of Egypt broke off sharply where the land surface extended beyond the beneficent influence of the Nile, and so was shut in by a desert wall; in the same way the flourishing countries of the Mediterranean's southern shores stretch little beyond the Sahara's borders. Similarly the trackless wastes of the Himalayas cut off India from its continent, and mountain-ranges sever France from Spain, Norway from Sweden, Italy from Central Europe, and so on. The dividing force of mountains is not limited to a single main range, but takes effect in every spur and offshoot. Thus we find valleys north and south of the Rhone and in the Austrian Tyrol, where the people, similarly occupied and not geographically remote, are completely cut off from mutual intercourse, and their severance has expressed itself for centuries in the development of different modes of thought, language, religion, and national dress.[1]

Rivers do not form very persistent boundaries unless their width is great, for the conditions of both banks of a river are similar, and therefore a people that can establish itself on one bank soon desires the other also. This was the case in 1870, when Germany, in a frenzy of sentimental patriotism, demanded both banks of the Rhine. Nevertheless, a river is a very convenient dividing line when neither side is in the predatory stage of its existence, or when there is nothing to be gained by trespass.

[1] So complete is this isolation in the remoter valleys of the eastern Tyro that an ancient Ladin woman and an English girl, happening to meet at the village inn, were both struck dumb with amazement at one another.

A river boundary has often been chosen because of its convenience, as, for instance, the Torneå between Russian and Swedish territory, the Rhine between Switzerland and Germany, the Rio Grande between the United States and Mexico. The great disadvantage in the sharing of a river valley by adjacent states is that every state in modern times needs an outlet to the sea,[1] and consequently the river-mouth is of untold value to the people who possess it. Thus Germany, although she held both banks of the Rhine, knew she would have her fortune made as a nation if she could get its mouth; we may thus explain the fact that the violation of Belgium's neutrality was the *first* step in the recent war, although hostilities ostensibly began on the eastern side.

Other boundaries exist besides the physical ones given above. These are race boundaries, and so belong to an entirely different category. They are due to the fact that settlers in, perhaps, widely separated areas have expanded until they finally touch each other's borders. The Chinese built an immense wall round their country, but even this did not suffice to protect them from the incursions of the hardier steppe-dwellers, and the meeting of diverse races in this way has often resulted in the conquest of one by the other, and so in a general shifting, or, possibly, a fusion of the population. Thus these boundaries tend to be broken up and re-formed elsewhere. Again and again, in historical times, the great leader has arisen in one part of the world or another, and then all artificial boundaries that stood in his path have been swept away, the only kind of divisional line that has withstood such treatment in the long run being the natural geographical boundaries above mentioned.

## XXX. Movements of Population and the Establishment of Intercommunication

Having established the geographical reasons for the settling of certain peoples in certain parts of the world, and for their concentration in particular parts of these areas, it next becomes

[1] Switzerland has no marine outlet, but Poland has a 'corridor' ending at Putzig and some rights in connexion with the port of Danzig.

necessary to explain the movements of population. From the very earliest times a constant shifting has been going on, and Dr. Haddon, in his little book on *The Wanderings of Peoples*, attributes it to two main causes :

1. Migration due to expulsion, which takes place owing to dearth of food, a too frequent result of over-population.

2. Migration due to attraction, when hardy tribes, living on arid steppes or on plateaux, swoop down on the prosperous but peace-loving valley-dwellers and insist on sharing their riches, either settling among them or carrying off all they can lay hands on.

1. *Migrations of expulsion.* We believe that the first of these types of movement, which is by far the more widespread, has been taking place on a very large scale from the very earliest times, in consequence of the increasing desiccation of Central Asia. Asia was certainly, in the beginning, a far more habitable continent than Europe, because in early times, when only stone weapons were used, it was impossible to effect adequate and permanent clearings in a region of lowlands covered with dense forest growth. In Central Asia, on the contrary, vegetation was sparse, except in river valleys, the surface being more generally elevated and more cut off from marine influence than was the case in Europe; thus broad open stretches of country were available for occupation.

We saw in the preceding chapters that human development took place most swiftly in the valley peoples of the Nile, Euphrates, Tigris, and Indus, and we have reason to believe that the vast plateaux surrounding these great rivers were, at the same time, the abode of numerous wandering races. As these tribes increased in numbers, hunger alone would provide the incentive for migration, and it seems probable that to this cause we may ascribe the almost universal westward drifting of the peoples of Asia, which sometimes brought them, as marauders, into conflict with the more settled inhabitants of Europe. It does not follow that the inhabitants of Europe necessarily all came from Asia; in fact, as shown above, evidence points to the contrary, but we know that successive waves of population, due either to peaceful

drifting or to warlike incursion, broke on eastern Europe, pushing the previous occupants of the land further and further west. A peaceful drifting of this sort was seen in the gradual occupation by the Slavs of a part of central Europe previously held by the Teutons, whereas the Tatar invasion of the thirteenth century, which consisted mainly of peoples of Turkish origin, spread over the eastern portion, forcibly driving the former occupants as refugees northward and westward.

Another kind of expulsion, due to religious, political, or social differences, has also led to fairly extensive migrations. The Hebrews, for instance, left Egypt and sought the Promised Land. Later, the Pilgrim Fathers formed the nucleus of the New England State, and in modern times the Boers voluntarily abandoned Cape Colony, establishing themselves beyond the Vaal and Orange rivers for the sake of attaining freedom.

2. *Migrations of attraction.* Migrations of attraction originated in ancient times, as stated above, in consequence either of actual need or of desire for gain. The earliest mention in history of this kind of migration was that of the little tribe of nomads of whom Terah, Abraham's father, but later Abraham himself, was chief. Dwelling originally at Ur of the Chaldees, a place at the head of the Persian Gulf, Terah, with all his family and dependants, sought the fertile land of Canaan. The route thither was greatly prolonged owing to the fact that westward lay the desert; they therefore travelled north-west, along the Euphrates valley, reaching first Haran, where they stayed some time and Terah died. Abraham subsequently continued the journey, now in a southward direction, and the Promised Land was reached.

Later in history, Medes and Persians coveted and finally took possession of Babylonia, in the rich valley of the rivers; again, Rome, wealthy and powerful, more than once became the prey of barbarians from without.

In both ancient and modern times, migrations of this sort have been the natural result of conquest; thus the Moors left a lasting impress on the art and architecture of Spain, and uncertainty was recently felt as to the results of a plebiscite in Slesvig because of German infiltration.

Migrations of attraction have taken place in modern times for different reasons. The spirit of adventure, combined with a desire for more scope, led to the gradual colonization of the western states of North America by dwellers in the eastern. A desire for speedy acquisition of wealth prompted the Spanish treasure-raids of the sixteenth century, and, in modern times, the numerous gold-rushes to various parts of Australia. The later gold-seekers in the latter country have now, in large measure, addressed themselves to the less adventurous, but in most cases the more profitable, occupation of sheep-farming. Through such migrations the most unpromising regions have become centres of population, and several parts of the world are inhabited that would otherwise have long remained unpeopled.

The details of the various migrations that have taken place do not come within the scope of general geography, and the present distribution of peoples, which is very important from the geographical point of view, must be studied under the regions where they occur. For this reason only a few isolated examples are given here, enough to prove that constant movement is going on, but a very interesting account of the most important migrations is given in Dr. Haddon's little book, mentioned above. The studies of countries in detail is greatly complicated by past movements that have taken place, and also by the fact that a country is very rarely an ethnic unit, so that a geographical boundary does not necessarily mean a race or even a language boundary. Thus Switzerland is bounded by the Jura, the Rhine, the Inn, the Alps; but the French language has crossed the Jura German is spoken on both sides of the Rhine, Romansch is heard both in Swiss and Austrian territory, although they are separated by mountains and the Inn, Italian also is wedged in with German Swiss between the Alpine passes.

To take another example, Spain, which is definitely cut off from other countries by the Pyrenees and the sea, contains within itself at least three distinct racial elements, the result of former migrations. These are:

1. The primitive Iberians, the Mediterranean race of Sergi, represented, where comparatively unmixed with other elements, by the Basque peoples;

2. Branches of the Indo-Germanic or Aryan tribes, forming part of the early Aryan invasion of Europe;

3. An Arab element, due to five centuries of conquest.

*Establishment of lines of communication.* Leaving then the detailed study of migrations to be dealt with in the special cases affected by them, it is next important to realize that movements have not taken place arbitrarily, but have followed certain natural geographical lines, clearly lines of least resistance, and these have, from the earliest times, formed kinds of highways for the passing and repassing of the more restless portions of humanity. These lines, established first as outlets, gradually became lines of *communication*, as nuclei of population formed at either end, and lines of *intercommunication* as further settlement took place along them.

We saw above that the earliest concentration took place along certain river valleys, namely, the Nile, Tigris and Euphrates, Hwang-ho, Indus; later also along the Ganges and the Yangtse-kiang. Almost simultaneously, or but little later, another phase of concentration was beginning in the eastern part of the Mediterranean basin. Doubtless at first the communities in the river valleys were scattered along the banks, as the people gained their livelihood by agriculture; in this case the river itself would at first form the highway of communication. As, however, a higher stage of civilization was reached and human wants multiplied, there was need of intercourse not only between neighbours on the same river-bank, but also with peoples outside; we have clear indications of such intercourse as early existing between the river valleys of the Euphrates and Tigris and that of the Nile. This intercourse was, however, not always of a peaceful nature, but sometimes took the form of conquest; even so, armies usually followed beaten tracks, if such existed. The establishment of these beaten tracks or trails (fig. 149), and their gradual transformation into roads or finally railways, is of the greatest importance to the geographer, as showing how the various populous areas became linked up, what kind of needs became paramount, and to what outside influences the people have had access. Moreover, the formation of these ancient route-lines has generally

resulted in the emphasizing of certain natural features such as passes, valleys, &c., and the obliteration of others.

The course taken by these routes gives a stimulus to new settlements at favourable points along it, so that, in the end, we get main centres, remote from each other, linked together by a kind of artificial reproduction of the old river-highway type of settlement, the main road replacing the river as a means of transit.

FIG. 149. The 'Roman Steps' near Abergele, North Wales, showing the establishment of an ancient track or trail. This is a paved causeway winding for some distance among the hills. (From a photograph by C. L. Skeat.)

*Communication between Nile and Euphrates regions.* The first *historical* evidence we have that the rivers of the Persian Gulf and that of Egypt were not wholly unconnected may be gathered from Abraham's journey already mentioned. From Ur, a city just on the desert rim, north of the Persian Gulf, he proceeded up the Euphrates to Haran[1] and thence to Canaan, where he remained until driven by famine into Egypt. As the date of the Call of Abraham is generally reckoned as about 1921 B. C., we judge that his arrival in Canaan took place somewhere about 1920 B. C. Traces of Babylonian influence are found even earlier, however, in Egypt, in the form of cylindrical seal-stones, which are believed to have been of Babylonian origin, but which were superseded by the characteristic beetle-shaped scarab prior to the fifth dynasty (*c.* 3000 B. C.). The introduction of a different kind of burial also seems to show that the religion became more assimilated to that of Babylonia at this time, and other evidence points the same way. Possibly a line of communication con-

[1] The name of this city is expressed in cuneiform by an ideograph meaning 'road', this being the crossing-point of the Syrian, Assyrian, and Babylonian trade-routes; see Ezek. xxvii. 23 for inference that a trade-route existed between Haran and Tyre.

nected a certain part of the Nile basin with that of the other rivers; one might, for instance, cross the Red Sea near Kosseir and pass along a wady leading at right angles to the coast, towards a part of the Nile valley, where it curves towards the sea. If this line of communication existed, it would have been the oldest connecting the great river valleys by land, as signs of outside culture appeared earliest in that part of the Nile basin.[1]

While this may have been the oldest route, we believe that the one using Palestine and the Sinai coast as a land-bridge is also of great antiquity, and may have formed the chief line of communication between Mesopotamia and Egypt; the Ishmaelites, to whom Joseph was sold by his brethren, were following this route in the ordinary course of their trade, conveying spices, myrrh, and balm from their places of origin in the East to Egypt, and passing through Shechem on their way. This is the earliest mention of a caravan-route.

*The 'Royal Road'.* Asia Minor, placed as it was between the busy population of the Aegean and Egypt on the one hand, and the rich valleys of Mesopotamia on the other, was naturally the first country to develop a long and important highway. The most famous route of ancient times, the 'Royal Road' (fig. 150), traversed this peninsula from west to east and connected the Aegean ultimately with Persia or Elam, passing through Babylonia and Assyria on its way, and perhaps penetrating also into India. It was called 'Royal' because when Persian power was at its zenith, the service of the great king passed that way, and it formed the administrative outlet to the most distant part of his dominions. The direction taken by this road long presented a difficulty, as it followed the northern of the two possible routes across the salt lake and desert parts of Asia Minor, which was both less direct and more difficult than the southern route, if

[1] Elliot Smith has collected a considerable amount of evidence to show that intercommunication took place by sea perhaps even earlier than by land. The Sumerian vessel described in the 'hymn of enthronement' showed Egyptian influence as to helm, oar, and mast, suggesting that even then a maritime link existed between Egypt and Babylonia: see Elliot Smith, *Ships as Evidence of the Migrations of Early Culture* (Longmans, Green & Co., 1917).

Persia was its goal. This difficulty vanishes, however, if we follow Professor Ramsay in believing that the road's direction was due to the attraction exercised by the then important city of Pteria, which stood on the site of the present Boghaz Keui. This city, which to the eye of the great king's emissary must have appeared as an imposing pile of ruins, is believed to have been the ancient Hittite capital, placed at the cross-way of the

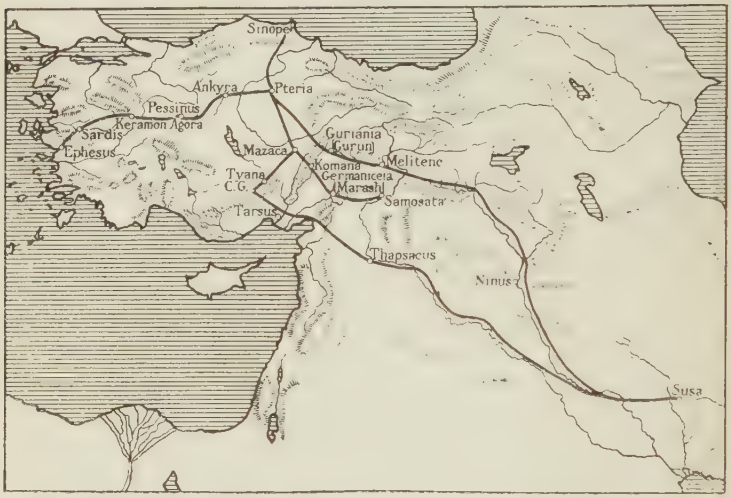



FIG. 150. The 'Royal Road' connecting the Aegean with Mesopotamia and Persia. C.G. Cilician Gates.

two chief roads. The north to south road, which was met here by the 'Royal Road' from the west, led on the one hand to the Cilician Gates, on the other to Sinope,[1] an ancient port which had already declined in the days of Strabo (64 B. C. ?). The discovery of archives dating back to at least 1400 B. C. on the Boghaz Keui site, and the presence of Hittite monuments along the line of the road but nowhere else west of the Halys, testify to the antiquity of the route[2] and also to the long duration and wide

[1] Founded by the Milesians perhaps about 630 B. C.

[2] The road is believed to have been known to Aristagoras, and was therefore already existing in 600 B. C.; Professor Ramsay puts it as probably earlier than 900 B. C.

extent of the kingdom of the Hatti, which seems at one time to have controlled the west coast of Asia Minor, and was in communication both with Mesopotamia and Egypt. In the swaying balance of power the city of Pteria was destroyed more than once, but had been rebuilt with something of its former splendour, and belonged to Media, when it finally suffered hasty demolition about 546 B.C. at the hands of Croesus, King of Lydia, in a last desperate effort to stop the advancing tide of Persian conquest. Thus, when the Persians under Cyrus swallowed up Assyria and Babylon, and advanced westward into Asia Minor, we believe they made use of the old track already existing across the peninsula, rather than construct for themselves a more direct route.

The course of the 'Royal Road' is described by Herodotus as passing, during the Persian period, from Ephesus, by the Cilician Gates, to Susa. After leaving Ephesus it passed to Sardis, keeping north of the Maeander valley and also north of the salt lakes and marshes. Continuing nearly due east, it crossed the Halys by the famous bridge above mentioned and reached Pteria, where it met the caravan-route from the north. This, the western part of the road, has been traced in detail by Professor Ramsay, by means of ancient Hittite monuments which marks its course. The direction taken by the 'Royal Road' southward and eastward from Pteria is left vague by Herodotus, but Professor Garstang has lately recognized deeply-incised ruts on rock surfaces, similar to those seen by Professor Ramsay, and these seem to suggest that the route passed southward through Tyana and so to the Cilician Gates, crossing the Euphrates at Thapsacus, a crossing-place believed to have been used both by Xenophon on the outward march, and by Alexander. At the same time there is evidence also of communication along two other lines, i.e. a fairly open route by Gurun and Tochma Su, and a more direct but rockier route by Kuru Bel and Komana; it is not clear by which of these three the 'Royal Road' itself entered the Euphrates valley.[1] If either of the two latter routes were followed,

[1] Tozer thinks the measurements given by Herodotus prove that this writer is not referring to the well-known pass of the Cilician Gates, but

the road probably crossed from the upper course of the Euphrates to the Tigris at Samosata, passing down this river valley as nearly as possible to Susa.

*The southern commercial road.* Another route, which probably for about 600 years formed the great Graeco-Roman highway between east and west, was the easier one, leading along the southern borders of the Asia Minor plateau. When the peninsula ceased to have any central government within itself, and became merely an outlying province of an eastern empire, the northern route lost its meaning, and the immediate need was an easy passage for merchandise between the Euphrates valley and Persia and the civilized centres of the Mediterranean seaboard. The characteristic features of the road, which skirts the central desert, and has a happy way of circumventing obstacles rather than surmounting them, point to its origin as a genuine trade-route. The occurrence along it of Greek-named towns suggests also its pre-Roman origin, although it is not actually mentioned till about 100 B. C. Further indirect evidence seems to show that it had then already existed for some 200 years, and it continued a chief highway until the rise of Byzantium began to deflect the main routes in the direction of that city.

*'Royal Road' (India).* A route across northern India from the Indus to the Ganges is mentioned by Megasthenes, the Greek ambassador at the court of the native king about 290 B. C. This road, also known as the 'Royal Road', passed from the Indus valley across the Punjab, and following part of the courses first of the Jumna and then of the Ganges, reached the capital, Palibothra (probably near Patna), near the head of the Ganges delta, extending thence to the Ganges mouth. About 300 years later the Periplus[1] of the Erythraean Sea (the Indian Ocean) mentions the port of Barbarike on the navigable mouth of the Indus, and this would serve as a coastal outlet of the 'Royal Road'.

to one of the passes through the Taurus Mountains between Melitene and Samosata, probably the Komana route referred to above: see Tozer, *History of Ancient Geography*, p. 91 and map.

[1] The Periplus is supposed to date from about ten years after Pliny's death, which date is fixed by that of the great eruption of Vesuvius, A.D. 79, in which he perished.

*Early trans-Asiatic routes.* The Periplus also establishes, by inference, the existence of two other overland routes at this time, as not only Barbarike, but the even more important port of Barygaza, at the mouth of the Namnadus (Nerbudda), were both trading in silk and furs with the great city of Thinae. The land of This (China), where the city was situated, was far away towards the north, and bordered on the eastern ocean. One of these routes passed through Bactria to Barygaza, and may have coincided in the Kabul region with that followed by Alexander; the other is vaguely referred to as passing to the Ganges mouth.

A continuation of the first route northward has already been described by Pliny and later by Strabo as an existing trade-route from India (perhaps meaning Kabul) to the Caspian in the time of Pompey. The merchandise was carried by land through Bactria, then along the river Icarus (not so far identifiable) to the Oxus. By the Oxus stream it was conveyed to the Caspian Sea (the Oxus then possibly opened into the Caspian), and so across the sea and up the Cyrus river. Thence by only five days' land-transport it reached the Phasis and so the Euxine.

The existence of a portion of a very early easterly, or rather north-easterly, route is hinted at by Herodotus, who relates how the Greek colonies of the northern Black Sea coast, of which Olbia was the chief, carried on an extensive trade with the Scythians. The description of the land, which is frozen for eight months of the year, and where the air is full of feathers, points to the northern regions of Russia or Siberia, and the gold, obtainable by theft from the gold-guarding griffins, might emanate either from the Ural or Altai Mountains. It may have been this route that subsequently crystallized as the main northern caravan route through Asia. There are many indications, also, that a route extended from the Black Sea to the Adriatic, passing up the valley of the Danube and its tributary the Save, and this fact, taken in conjunction with that of the route mentioned above, would seem to show the existence of a possible highway across the greater part of the two continents in a more or less east and west direction, establishing, not a continuous route perhaps, but a succession of stages.

Sir W. Ridgeway points out that, in pastoral countries, an identical currency standard obtained, ultimately connected with the value in gold of an ox. It is therefore noteworthy that along this east and west way no insuperable obstacle of sea or forest occurs to make exchange of cattle impossible, and we are, moreover, confronted by the curious fact that, whereas in Persia a physician would heal the master of a house in exchange for an ox of small value, in England he receives his fee (ox) [1] for a similar service. For these reasons we are justified in concluding that intercourse of some kind was carried on between east and west. The European part of this road was existent at any rate in Greek times, and the *Book of Marvels* relates that by means of it travellers from the Danube could reach the Adriatic, and that along the way common marts were established for merchants to display their wares. For the encouragement of traders the road was placed under the special protection of Herakles, and, if any one travelling along it suffered wrong, those who dwelt in the vicinity were made responsible.

*Tin and amber routes in Europe.* In addition to this east and west route, the trades of tin and amber supply evidence that a few roads across Europe were in existence, perhaps even in prehistoric times, in spite of the difficulties of transit in a north and south direction.

The period at which amber from the Baltic first began to find its way to southern and eastern markets is difficult to determine, but it is a question of great interest, as it necessitates the existence of a land-route. References to amber in the *Odyssey* show that it was then, in the early Iron Age, already known in Greece, but there is reason to believe that it had been used for some time before amber beads became a recognized adornment for Greek beauties. In the countries of the north, ornaments of amber existed in neolithic times, and although the later Stone Age of these regions overlaps into the Bronze Age of the south, yet even there amber was not unknown at that period, some having been found by Dr. Schliemann in a tomb at Mycenae. The fact that during the succeeding Bronze Age in the north the

[1] Compare the German *Vieh*, cattle.

use of amber nearly ceased, does not militate with the idea that it may have still been greedily sought by foreign merchants, with whom it had not lost its appeal, but rather suggests increased export facilities. This would necessitate an existing route from the Baltic shores to some Mediterranean port, and Pliny tells us that in his day such a route passed from the coast through Germany to Pannonia (Hungary), and crossing the Danube at Carnuntum (Bratisleva), reached the head of the Adriatic.[1] It remains to discover what people had been instrumental in establishing the route, and there is considerable evidence to show that the goods thus conveyed were displayed in Etruscan markets. The rise of Etruria into a position of importance in northern Italy is traceable towards the close of the Bronze Age, about 1000 B. C., but even earlier her people, if identifiable with the Tyrrhenes, possessed a navy so powerful, that in 1500 B. C. it made a formidable attack on Egypt. The large amount of gold and silver found in Etruscan tombs testifies also to accumulated wealth, and we believe that Greek and Phoenician merchants competed eagerly in Etruscan markets, not only for the produce of the fields and forests, which was considerable, but also for the metals and amber conveyed thither by Etruscan traders from the north. There are several indications that the influence of Etruria extended in a northerly direction, discoveries of Etruscan weapons having been made along the lines that the traffic would be likely to take, also Scandinavian metal-work of the period bears traces of Etruscan inspiration. Supposing the route given by Pliny were the first and main trade-route, it seems probable that others existed, at any rate subsequent to the voyage of Pytheas, who was sent out in the fourth century B. C. by Massilian merchants, for the express purpose of locating the Tin Islands. Opinions differ as to the position of these islands, but Pytheas certainly sailed northward, and there seems reason to suppose that Cornwall and the Scilly Islands were his immediate goal, and that it was this region the Phoenicians had been in the habit

[1] Boyd Dawkins finds evidence of two amber routes, both terminating at Hadria (Adria) on the Adriatic : see *Early Man in Britain*, p. 466.

of visiting by sea. Tozer[1] shows how, by an ingenious comparison of passages, Pytheas has been made to admit by inference the existence before his time of an overland route through Gaul, probably down the Rhone valley to Massilia. When the Gauls burst through the Alpine passes into northern Italy, it seems likely that the Etruscan routes were for a time disturbed, and the amber trade may then have passed into Greek hands. Discoveries of amber, Greek coins, &c., have enabled Boyd Dawkins[2] to trace a possible route from the amber coast to the Black Sea, terminating in the Greek port of Olbia, which route may have become established before the reopening of the old route along the lines described by Pliny.

*Two main caravan-routes across Asia.* Later on, two main caravan-routes became established across Asia. Of these, the northern one, identical perhaps with the early route mentioned above, passed south of the Altai Mountains, skirting Lake Balkash and the Aral and Caspian Seas on their northern side, so that travellers along it finally reached central Europe by way of the Black Sea. This route would be joined near the Oxus by that mentioned above as already used in the time of Pompey.

The other east and west route could only pass between the Kuen-lun and Thian-Shan ranges, and would lead by Kashgar and Bokhara to Basra (Bassorah) or Ormuz, the latter becoming on this account a well-known trading station during the Middle Ages, frequented first by Arabs, then by Portuguese. These two routes were followed in the main by the Polos, and Marco Polo, on his second outward journey, took the second of these, reaching Ormuz by way of Nineveh and Bagdad, the latter city being a centre of communication between India and Persia and the west, both by land and water.

*Intercourse between Europe and the East.* After the main scene of world activity had shifted from Asia to Europe, the crusades, and the impetus to civilization given by them, made this continent depend more and more on the luxuries obtainable from the East. At that time, when sanitary science was unheard of, scents of

[1] See Tozer's *History of Ancient Geography*, pp. 33, 155–7.

[2] See Boyd Dawkins's *Early Man in Britain*, p. 474.

all kinds played a really important part and ranked with the necessities of life. The incense for all the churches of Christendom came from the Levant, and spices, which were much used in cookery, came from still further east. Not only this, but drugs were obtained from India through the Arabs, silk was only produced in China, precious stones and gold were brought from India. A selection from the list drawn up by Barrett in Hakluyt's *Voyages* is given in Jacobs, *Geographical Discovery*, p. 89, and shows to some extent the enormous proportions that eastern trade had assumed in 1584.

*Pilgrimage routes.* The important part played by pilgrimages in certain religions also had something to do with the establishment of routes and even of trade-routes, for the Mohammedan pilgrim did not hesitate to combine business with religious duty. The pilgrimage as a means of grace was recognized in three religions:

1. Brahmanism:[1] the pilgrimages along the Ganges were probably the earliest known;
2. Mohammedan: in this religion the pilgrimage was of primary importance;
3. Christian.

The Hindu makes a pilgrimage along the Ganges, if possible from its mouth to its source.

In Mohammedanism the pilgrimage is considered the duty of every pious believer. The pilgrimages that are conducted on a large scale and have great commercial importance take place annually, and all have regular fixed routes converging on Mecca.

In the Christian religion pilgrimages were first made to places of historic association, as in the Holy Land. Later they were made to Rome, as the centre of Christendom, or to any shrine of special sanctity or repute.

*Roman roads.* The great road-makers of history were the Romans, and it seems probable that, without the military discipline and engineering skill of this great people, Europe (fig. 139) would have remained some hundreds of years longer in an extremely backward condition. Roman roads, good examples

[1] Later the pilgrimage also became a feature in Buddhism.

of which abound in our own country, are characterized by certain features which mark them off from roads of the present day, thus :

1. They followed a straight line regardless of the fact that it is often easier to avoid obstacles by circumventing them, even if by so doing the distance is somewhat increased. Thus the Roman road near Goathland runs straight up the hillside, ignoring the winding valley-bottom which runs parallel with it for a short distance.

2. The causeway is built rather than made. A good example of this is seen near Gilsland in Cumberland, where the road runs on the top of the wall. The Roman road near Goathland shows the actual way in which the road was built up with large slabs, although the surface itself has been removed.

3. They often triangulate the surface with a town at each angle ; thus London, Colchester, and Canterbury make a triangle, one side of which is formed by sea.

4. The military roads are guarded by chains of forts. Such forts are traceable on the west coast of Britain between Deva (Chester) and Caerleon-on-Usk, which were two of the three main military centres, the third being York. They also occur in other parts in a line parallel with the west coast.

5. The towns are often strung along the main roads at a distance of about 30 to 50 miles, i. e. a day's march from one another. Thus the Fosse Way, which connects three places on the south coast—Exeter, Dorchester, and a place near Seaton—with Lincoln, is punctuated by Ilchester, Bath, Cirencester, then, after a gap, High Cross—where it cuts Watling Street—and Leicester. Similar stages on a high road are Orleans, Tours, Poitiers, and Angoulême, between Paris and Bordeaux.

It is noticeable that the chief highways of Europe still follow the course of the old Roman roads, and we can trace a distinct difference in culture in countries where they never penetrated.

*Water-ways.* We have seen that the oldest communities were all established on water-ways, and it seems probable that the oldest of all routes, or at any rate those that were of any importance, were water-routes along rivers or narrow seas. The dense

forest growth always formed an insuperable obstacle to progress, whereas, so soon as the floating log has suggested the dug-out, the means of communication between opposite banks and along navigable streams becomes simple and easy. Even the inland sea is less 'pathless' than the forest, and the water-way has further a distinct advantage in that only the vehicle has to be produced, the way needing neither making nor repairs. Even in the case of water-ways, however, certain difficulties have to be overcome. In rivers, for instance, much depends on their navigability; in the ocean, tides and currents have to be reckoned with, and, after the introduction of the sailing-vessel, winds also. For this reason we notice that the most important towns of the Nile are above or below the cataracts, and in the case of rivers generally the largest towns are in the middle or lower course, where the volume of water is greater and the slope less than higher up. In Africa, where the centre of the continent is table-land with a sudden drop towards the coast, the navigable part is the middle course, so there and at the mouth are the chief settlements.[1]

*The origin of seafaring vessels.* As mentioned above, a curious assemblage of customs occurring in widely separated areas is of too fantastic a nature for us to suppose that the conjunction of ideas can have originated sporadically. Elliot Smith, in his *Migrations of Early Culture*, proved that these customs were connected with that of Sun-worship, and his map of Heliolithic culture (see fig. 137) shows their probable source of origin and extent. It is impossible to believe that this culture was disseminated otherwise than by sea, and in a later work Elliot Smith

[1] This is well illustrated by the case of the Congo, where it was only with the greatest difficulty that either road or railway could be constructed to connect the middle course with the navigable mouth. Now, the railway, running from Leopoldville to the coast, has opened up communication with the part above Stanley Pool, which is navigable by large steamers at all seasons of the year for a thousand miles. Along this middle course of the great river, native settlements extend for miles, but the country has been too little explored for any estimate to be made as to the density of the population. Goods are conveyed from the interior by water to Leopoldville, and thence by the railway to Matadi, whence direct trade with Antwerp, Liverpool, &c., is carried on by steamer.

traces the probable beginning of the shipbuilding craft also to Egypt, adducing evidence to show that actual sea-going ships date from a far greater antiquity than had been previously supposed. The earliest known drawing of a seafaring vessel is seen in pictures of King Sahure of Dynasty V (*c.* 2600 B. C.), and boats to be seen on the river Irrawady at the present day bear a strong family likeness to these. In this connexion it is noteworthy that Sumerian civilization first arose on the shores of the Persian Gulf, and the Babylonians themselves looked on the sea as the source of their cultural advancement. Maspero quotes the tradition of a fish-like monster which, rising out of the Erythraean Sea, taught the people the use of letters, sciences, and arts, the rules for the founding of cities and construction of temples, also the principles of law, land-surveying, and agriculture. So many features link together the early civilizations of Egypt and Mesopotamia that possibly the coast-line of south Arabia forms a closer tie between the two culture centres even than the well-known land bridge of the Syrian coast-plain.

It has been frequently noticed that, when an immigrant race introduces an advanced kind of culture to any region, the backward aborigines do not necessarily respond to such a stimulus unless, for some reason, compulsion is used, or some direct gain offers, as in the case of the finding of gold, pearls, &c. This fact also serves to explain why a method of shipbuilding, which has been obsolete in its place of origin since the Early Bronze Age, may still persist as a type in remote parts of the world.[1]

*The navigation of inland seas. The Mediterranean.* As regards inland seas, the oldest water-way was the Mediterranean, and it has till recently been assumed that the Phoenicians were the earliest navigators of these waters; evidence is, however, accumulating to prove that they were preceded, at any rate in the eastern basin, by the Cretans of the Minoan Age, who were, probably, skilful mariners and possessed quite a considerable fleet. Further light will perhaps be thrown on this subject as

[1] Compare the drawings of Egyptian ships of the Pyramid Age with the rice boats of Burma, or the Swedish rock-drawings of about 1000 B. C. with the present double-prowed vessels characteristic of Uganda.

more is discovered about Knossos, the great sea-town, but the following facts are known :

1. Aegean civilization was identical on the mainland and islands, so there must have been free intercourse by sea ;

2. Some of the most important seal-impressions, so far discovered, represent ships ;

3. The islanders had communication with Egypt, as Niliotic influence is traceable on some Cretan vases, &c. ; also vases of Middle Minoan Age and apparent workmanship have been found in Egypt ;

4. In Homeric times, Cretans were still competing with Phoenicians as bold and adventurous navigators.

So long as the Cretan fleet was supreme in the eastern Mediterranean it sufficed to keep the Phoenicians out of the Aegean. When, from about the fourteenth to the twelfth century B. C., Minoan centres were broken into by invaders from outside, the destruction of their sea-power laid these waters open to the Phoenician trader, but the newly-established Greeks soon began to explore the coasts, and the result was a kind of neck-and-neck race between the two peoples for the dominion of the sea. Their interests, however, were not the same. The Greeks, early becoming somewhat cramped within the narrow confines of their land and being at first an entirely agricultural people, needed more space for cultivation, so established colonies for this purpose. The Phoenicians, on the other hand, required markets for the goods that they gathered up in rich abundance from the various already advanced river-valley centres of the east. To the Syrian coast, where the great cities of Tyre and Sidon rose to fame, flowed all the wealth of the eastern markets, and streams of Phoenician galleys bore it thence to their other markets in the west. The Greeks of Homer appear to have accepted the presence of the Phoenicians in their home waters for purposes of commerce, but when they themselves began to cultivate commercial interests also, we find that where the two peoples came into conflict,[1] as in Cyprus and in Sicily, it was the Greeks

[1] In the Tyrrhenian Sea this power was shared for a time with the Etruscans, who at one time formed a powerful alliance with the Carthaginians against the Greeks.

and not the Phoenicians who were the first arrivals. On the north coast of Africa,[1] however, the Phoenicians found an almost free field, and it was there that the city of Tyre, about 813 B. C., established her greatest colony, Carthage,[2] destined later to become so mighty a thorn in the flesh of Rome.

It seems highly probable that the Phoenicians established themselves on the Libyan coast before venturing out into the perilous paths of the Atlantic; we may, therefore, suppose that, while the Greeks were tightening their hold on southern Italy, by encircling its gulfs and bays with flourishing little colonies, the Phoenicians were contemplating their great venture into the far west. Still the Greeks pushed westward also, so the founding of Massilia (about 600 B. C.) and the extension of Greek influence to the coasts of Spain may have just preceded, or been preceded by, the establishment of the Phoenician Gades (now Cadiz), which supplied the silver of Tarshish (Tartessos), hardly more valuable than the coveted tin for making bronze.

As regards the treasures of foreign workmanship and of oriental design and origin found in western Mediterranean sites, it is often impossible to decide whether they were conveyed thither by Phoenicians or re-imported by Greeks from Greece. It seems, however, safe to say that the Phoenicians were recognized as traders before the Greeks had turned their thoughts to commerce, and that, even after the Athenian navy came into existence, the merchant-ships of Phoenicia remained unsurpassed in size, though not perhaps in swiftness.[3] Thus the Phoenicians formed a kind of inland-sea prototype of nineteenth-century Britain on the ocean, and their supremacy in this respect was for a time acknowledged by the Greeks themselves.

Herodotus gives the founding of Tyre as about 2756 B. C.,

[1] Traditionally, Utica was their first colony in this region and was founded 1100 B.C. Beloch, however, gives reasons for doubting the authenticity of this date and considers Utica to have been later than Carthage. For this whole question see Beloch's *Griechische Geschichte*, given in Bibliography.

[2] The interments near this city carry it back to about 700 B.C., so perhaps the date 814–813 suggested for it may not be far astray.

[3] The Greeks called them γαῦλοι, 'tubs'.

which date may be mythical, but she had reached the zenith of her power about 800 B. C. and is still flourishing in 604 B. C., when Jeremiah foretells her destruction.

The immensity of her wealth and importance is clearly acknowledged by Ezekiel, about 583 B. C., when he threatens her with overthrow at the hands of Nebuchadnezzar, King of Babylon. The vivid word-picture[1] painted by the prophet calls up the whole scene before us. The beauty of line of the graceful ships riding at anchor, the blue background of sea and sky, framing the rich riot of colour due to hurrying humanity on the quays; the shouts of the herdsmen mingled with the confused neighing of horses and bleating of sheep, the shrill cry of the pilots, and, in addition, the subtle flavour of the breeze, laden at once with the delicate aroma of spices and the tainted breath of the sun-baked town; all the sights, sounds, and scents of the busy eastern port assail our senses through his description. Not only is one impressed by the vast activities of the port itself, but the proportions assumed by commerce at so early a date are quite startling; moreover, we have here definite evidence of the existence at that time of several trade-routes in connexion with the coast. Incidentally the prophet's words seem to show the continuance of the two ancient routes mentioned above. That the King of Babylon had access to the sea is proved by the threatened onslaught from that direction, and recalls the journey of Abraham, especially as Haran is here mentioned as one of the trading centres; the route from Persia would probably be an eastward extension of this. The mention of Egypt suggests the continuance of the caravan-route used by the Midianites when they conveyed Joseph thither from Shechem.

As Ezekiel's description shows, Phoenician trade was not confined to what might be considered the necessities of life, such

[1] A scene of this kind is depicted on the bronze gates discovered in the mound of Balawat in 1877. The gates were evidently constructed by the order of Shalmaneser II, in commemoration of his triumph over Tyre and Sidon in 859 B.C. A full description of the gates is quoted by Boyd Dawkins, pp. 453, 454, and they are preserved in the British Museum: see *A Guide to the Babylonian and Assyrian Antiquities*, second edition, 1908, pp. 35, 36; also Plates III, XVII.

as wheat, oil, wine, live stock, metals, linen, wool, &c., but included also luxuries such as coral, agate, precious stones, ivory, spices, embroideries, and dyes, these indicating a fairly advanced stage of civilization in the countries visited. All commercial secrets known to the Phoenicians were, however, most jealously guarded, and all sorts of tales were circulated by them to deter others from competition, so that, in the end, all their knowledge of geography and astronomy was unfortunately lost.[1]

The actual supremacy in the Mediterranean was wrested from the Phoenicians by the Greeks, although the famous Phoenician ports in the Levant never quite lost their prosperity till the time of the Crusades, up to which time also the trade with the Atlas lands still remained a Phoenician monopoly. The year following the taking of Tyre by Alexander was marked by the voyage of Pytheas, who was sent out by Greek merchants of Massilia specially to find the Tin Islands and brought back wondrous tales of distant Thule and the sea-water 'like jelly' in the extreme north, which served to stimulate curiosity in that direction. Already in the east, the old coasting trade from Syria along the south coast of Asia Minor had fallen into Greek hands, and in Asia Minor itself the Greek cities, by establishing colonies of their own on the Euxine, had captured Scythian trade. It remained for the new port of Alexandria to establish a flourishing trade with Egypt. Thus finally the whole Greek Empire was linked up by chains of colonial ports.

As the power of Greece declined so also did her naval strength, and Rome took her place as chief arbiter of Mediterranean water-ways, connecting them up with greatly improved land routes.

In the period following the division of the Empire into Western and Eastern and the subsequent decline of the Western Empire, trade in the west declined also and Mediterranean traffic was

[1] In a paper called 'An Attempt to reconstruct the Maps used by Herodotus' (*Geographical Journal*, vol. viii, p. 605), Professor J. L. Myres discusses the probability of the Phoenicians having a chart of the Mediterranean. Like the land-charts, he suggests that it was constructed about an axial straight line. The chief axis in the Mediterranean would be east and west, and would form practically a westward extension of the line of the Royal Road, a rigid notion of symmetry being then observed.

carried on chiefly by the Greek merchants of Byzantium and by the Arabs who had now conquered Alexandria. The devastating effects in the east, however, of the Crusades from the eleventh to the thirteenth centuries and of the incursions of the Turks in the fourteenth and fifteenth, resulted in the restoration once more of the Italian towns as intermediate stations between east and west, Venice especially rising to, and long maintaining, a unique position of wealth and importance.

*Decline of Mediterranean supremacy.* During the fifteenth century, the Portuguese, owing to their discovery of the Cape route to India, diverted a good deal of the eastern trade from the Mediterranean, and, in spite of the efforts made both by Venice and the Sultan of Egypt to maintain their position, it gradually dwindled. Meanwhile both Dutch and British competition threatened, and the wreck of a big Venetian argosy off the Isle of Wight coast in 1587 was symbolic of the passing of the eastern carrying trade out of Venetian hands on the Mediterranean into British hands on the Atlantic.

*Initiation of the Cape route.* The other main water-routes were due to the spirit of discovery, further quickened by the stories disseminated throughout the Middle Ages as to the fabulous wealth of the Indies; for this reason all the other trade-routes shaped their course in what was supposed to be the direction of these islands.

The eastward route to the Indies was originated, at the beginning of the fifteenth century, by Prince Henry the Navigator, and the various Portuguese expeditions sent out during his lifetime proceeded along East Africa southward, following the coast as far as Cape Verde and ending with the discovery of the Cape Verde Islands. All the early geographers had been very vague as to the southward determination of Africa, and most—with the exception of Ptolemy, who left it undefined—had represented it as running practically east and west from the north coast of the Gulf of Guinea to the Gulf of Aden,[1] for which reason navigators were encouraged to believe that this route to India might

[1] Africa was first circumnavigated in the seventh century B.C. by the Phoenicians sent by Necho, as mentioned by Herodotus. They sailed from the Red Sea to the Pillars of Hercules.

be even shorter than one by the Mediterranean Sea. The whole distance from Portugal to India was successfully covered by Vasco da Gama, in the same year, 1497, that John Cabot first landed on the mainland of America. The establishment of this route led to important results, for, in spite of its length and the difficulties encountered, the Portuguese continued systematically to follow up their successes in this direction and, within a few years, had formed colonies at many important points all round the Indian Ocean. In 1521 they seized the Spice Islands, discovered ten years before, and had thus already increased their commerce when, in the same year, the capture of Egypt by the Turks closed the gates of the Mediterranean, thus diverting the main current of eastern trade, hitherto flowing through Venice. The Cape route thus became of first importance and the other nations of the Atlantic seaboard were not slow to realize it, and also that their position as regards eastern trade was now nearly as favourable as that of Portugal. Thus the Dutch, French, and British gradually became formidable trade rivals, their rise into prominence being, however, mainly bound up with the Atlantic rim development sketched above. Even after the opening of the Suez Canal, although a great part of the eastern trade returned once more to Mediterranean channels, yet, in the case of Britain especially, many of her cargo vessels to India still rounded the Cape, and the number of ships passing thither from British ports was further increased by the vast development of African trade in the nineteenth century.

*The Transatlantic route.* The westward route, by which Columbus reached, as he thought, the Indies, was the first which entailed crossing the open ocean straight away and forsaking the land entirely. The danger of this was fully recognized by the crews, who mutinied several times, but Columbus was upheld by Toscanelli's map in the belief that only about 52°, i.e. 3,120 miles, intervened between the Azores and Japan. Fortunately for him, he discovered land about where he expected it to be, and for this reason concluded he had found what he sought, namely the westward route to India. The fact that this was a new continent lying between Europe and the Indies was proved later

by Amerigo Vespucci, after whom the New World was subsequently named.

*The Trans-Pacific route.* The route was completed by Magelhaéns, a Portuguese noble, under the direction of Charles V of Spain. Coasting down the east side of South America, the ships traversed the straits that now bear the name of Magellan and entered the new ocean, named by him the Pacific. After some months, they reached the Philippine Islands, where Magelhaéns was killed, and in November 1521 the expedition reached the Moluccas, the famous Spice Islands of the Indies. Great difficulties arose here owing to the monopoly by Portugal of the spice trade, and many of the men belonging to the Spanish expedition lost their lives, so that only 35 of the original 270 actually accomplished the first circumnavigation of the globe and returned to Spain. They were greatly surprised to notice that according to the ship's reckoning they had somehow lost a day.

This voyage was of the greatest importance as establishing the fact that the world was larger than had been thought, and that the new-found continent was separated from Asia by a huge intervening ocean ; in fact it was through this voyage that discovery for the first time outran theory, and Ptolemy's famous map, which had formed the basis of geographic knowledge for a millennium, became obsolete in a generation.

As a trade-route between Europe and the Indies, this could only be utilized by the construction of a canal across the Panama Isthmus, as has recently been done.

*Other attempted sea-routes.* All attempts to inaugurate trade-routes to the Indies by sailing round the coasts of Europe or America northward, with the idea of opening up the so-called North-West or North-East Passages, have completely failed, although they have called forth splendid examples of courageous seamanship. One of the first of these expeditions was, however, important as resulting in the first actual landing on the mainland of America by John Cabot.

*Summary of chief routes.* With the opening of the Suez Canal,[1]

[1] A coal-vessel first passed through the small canal from the Red Sea to the Mediterranean in 1865.

a great deal of the ancient importance of the Mediterranean Sea as a trade-route was restored. All the mail-boats now pass this way to India and Australia, the route via the Cape being used mainly for cargo vessels. The Mediterranean and Cape routes, therefore, still remain as two of the most important routes by water, the others being :

the Atlantic trade-route, foreshadowed by the voyages of Columbus, and which connects Britain with the coasts of Canada, the United States, the West Indies, and South America ;

the Pacific trade-routes, which were foreshadowed by the famous voyage of Magelhaéns, and which link up the west coast of America, the Pacific Islands, and the East Indies with the chief trading countries of the world.

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